VOLUME XXII NUMBER 2

BOTANICAL GAZETTE

AUGUST 1896

ON THE TOXIC ACTION OF DISSOLVED SALTS AND THEIR ELECTROLYTIC DISSOCIATION.[1]

LOUIS KAHLENBERG and RODNEY H. TRUE.

THE THEORY OF ELECTROLYTIC DISSOCIATION.

During the last decade work in physical chemistry has been characterized by a thorough and systematic study of solutions from both theoretical and experimental points of view. As a result of the activity along this line our knowledge of the nature of substances dissolved in various solvents has been greatly extended. In 1887 van't Hoff,[2] basing his argument upon the osmotic experiments performed by Pfeffer[3] ten years earlier, was enabled to show almost a complete analogy between the behavior of solutions and gases. This analogy grows out of the fact that when the volume of a solution and its osmotic pressure are taken into consideration the same laws hold as in the case of gases when the volume of the gas and its pressure are considered. So close is the analogy that, considering the temperature constant, the osmotic pressure exerted by a substance dissolved in a certain amount of solvent is the same as the pressure exerted by the gas if the same amount of substance is conceived of as being

[1] Abridged by the authors from a paper soon to appear as a Bulletin of the University of Wisconsin (Science Series).

[2] Zeitschr. f. physik. Chem. 1: 481.

[3] Osmotische Untersuchungen, Leipzig, 1877.

volatilized and as occupying the same volume as that possessed by the solution. Thus van't Hoff showed how the laws of Boyle and Gay-Lussac can be applied to dilute solutions. He was also enabled to make the following important extension of Avogadro's hypothesis: Equal volumes of all solutions having the same temperature and the same osmotic pressure contain an equal number of molecules, which number is identical with that contained in a gas having the same volume, temperature and pressure.

When Avogadro put forth his hypothesis that equal volumes of all gases under the same conditions of temperature and pressure contain an equal number of molecules, facts were found that apparently spoke strongly against this view. Thus it was observed that the vapor density of the chloride of ammonium was only a little more than half as great as was required by the principle of Avogadro, or, in other words, the molecular weight of the chloride of ammonium as calculated from the vapor density was found to be only a little more than one-half of that expressed by the formula NH_4Cl. This fact at first caused much opposition to Avogadro's views, which was finally cleared away, however, when it was shown that in the vapor of the chloride of ammonium there are not simply molecules of that salt, but also hydrochloric acid and ammonia molecules, the products into which ammonium chloride in the vapor state is largely dissociated.

The theory of van't Hoff had to contend with a similar difficulty. While the behavior of many solutions was such as to strongly support the theory, a large number of solutions (particularly aqueous solutions of acids, bases and salts) showed considerable deviation in their behavior from what the theory required, inasmuch as their osmotic pressures were greater than they ought to be according to the theory. The empirical results of Raoult,[4] which led to the methods for determining molecular weights of dissolved substances from the diminution of the vapor tension (or the elevation of the boiling point) of the

[4] Compare Ostwald, Lehrbuch der allgemeinen Chemie 1:715, 748.

solution or the lowering of the freezing point of the same, were explained from theoretical standpoints by the above mentioned work of van't Hoff, and so these methods were placed upon a thoroughly scientific basis. Solutions that showed too great an osmotic pressure also showed too great a diminution of the vapor tension or too great a lowering of the freezing point, and consequently too small a molecular weight.

In his mathematical formulæ van't Hoff for the time being arbitrarily introduced a factor i to account for the deviations that such solutions showed from what the theory required. Soon, however, Arrhenius,[5] from the relation between the lowering of the freezing point of solutions and their electrical conductivity, came to the conclusion that in aqueous solutions of salts, acids and bases, in short, in solutions that are conductors of electricity, the dissolved substances showing too small molecular weights (as did the chloride of ammonium in the vapor state) are to be regarded as being dissociated[6] into part-molecules or ions.[7] These ions are charged with electricity, each gram-equivalent bearing 96,540 coulombs. This latter figure has been determined by experiments on electrolysis and has well been termed the constant of Faraday's law. There are in a solution of an electrolyte as many ions charged with positive electricity as with negative electricity and thus the electrical neutrality of the solution is preserved.

Viewing things, then, in the light of the theory of Arrhenius, we have, for example, in a solution of sodium chloride, sodium ions and chlorine ions, besides a certain number of undissociated sodium chloride molecules. Experiments on the electrical conductivity show that in this case dissociation is practically complete when one gram-molecule (*i. e.*, $23+35.5=38.5$ grams) of the salt is dissolved in 1000 liters of water. There are at this dilution then in solution not NaCl molecules, but Na ions and Cl ions. These are usually written Na^- and Cl^+.

[5] Zeitschr. f. physik. Chem. 1:631. 1887.

[6] Because this dissociation takes place only in case of electrolysis it is termed electrolytic dissociation.

[7] A term that dates back to Faraday.

It has often been asked in what way Na ions and Cl ions differ from ordinary sodium in the metallic state and ordinary chlorine gas respectively. The difference lies in the energy possessed by the substances in the ordinary state and in the ionic state. Ten grams of chlorine ions, for example, contain less energy than do ten grams of chlorine. Supply the energy to the ions, as is done in the case of electrolysis, and the ions are changed to ordinary chlorine gas. The lack of understanding of this point at first caused much reluctance to accept the theory of electrolytic dissociation (or the theory of free ions as it is also called), notably on the part of English chemists.

Since Arrhenius published his theory of electrolytic dissociation, all investigations made on salt solutions have confirmed it. In addition to the lowering of the freezing point and the electrical conductivity, the elevation of the boiling point, the specific volume, and the optical and thermal properties of solutions of electrolytes, all strongly support the views of Arrhenius. This theory in the hands of Nernst[8] has yielded a clearer understanding of the processes that take place in voltaic combinations and has made it possible to calculate with accuracy in advance what the electro-motive force of a galvanic chain will be. It has enabled Ostwald[9] to place analytical chemistry upon a firmer scientific basis. In short, all the physical and chemical properties of aqueous solutions of electrolytes are well explained by the assumption that in these solutions the dissolved substances are split up into part-molecules or ions, and that the various properties that the solutions possess are due to the properties of the ions.

The more dilute the solution of an electrolyte is, the greater is the percentage of the dissolved substance that is dissociated, and only at infinite dilution is this dissociation complete. In the case of many substances, however, namely strong acids and bases as well as salts of these, dissociation goes on very rapidly

[8] See Nernst, Theoretische Chemie 563–569, where other references will also be found.

[9] Die wissenschaftlichen Grundlagen der analytischen Chemie, Leipzig, 1894.

as dilution increases, so that, as was pointed out above in the case of sodium chloride, dissociation is practically complete when an equivalent in grams is dissolved in 1000 liters of water.

Hydrochloric acid dissociates into H ions and Cl ions. A dilute solution of sodium chloride and one of hydrochloric acid both contain Cl ions. Their difference, then, is due to the fact that the former solution contains H ions, whereas the latter contains Na ions. To this difference are to be ascribed all the differences of properties that the two solutions possess. Solutions of all acids contain H ions, solutions of all chlorides contain Cl ions, those of sulphates SO_4 ions, those of nitrates NO_3 ions. Salts of copper in solution yield Cu ions, those of lead Pb ions, etc. In general, if BA represent the formula of a salt, B representing the basic radical and A the acid radical, then in dilute aqueous solutions this compound is to a greater or less extent dissociated into the ions B^+ and A^-, and, as stated, all the physical and chemical properties that such a solution possesses are due to the properties of the ions together with the properties of the undissociated molecules present.

THE PHYSIOLOGICAL ACTION OF DILUTE SOLUTIONS.

It has always been taken as axiomatic that the physiological action of any substance is due to its chemical character. *Now if, in the case of the solutions in question, all the chemical and physical properties are due to the properties of the ions plus those of the undissociated molecules it contains, it seems very probable that the physiological effect produced by such solutions is also due to these.* This thought, simple as it is, has to our knowledge never before been expressed.

Many investigations on the physiological action of aqueous solutions of salts on bacteria and higher forms of plant life as well as on animals have been made. The strengths of the solutions with which these experiments were performed have always been expressed in per cent. by weight; thus chemically equivalent quantities (*i. e.* molecular quantities) of the different substances were not compared, and it is probably for this reason that general considerations have entirely escaped observation.

If a very dilute solution of sodium chloride differs from a dilute solution of hydrochloric acid only in that the former contains Na ions and the latter H ions, then the poisonous action of the latter is plainly due to the H ions present. In like manner comparing a very dilute solution of sodium nitrate with a similar solution of nitric acid, the poisonous nature of the latter would be due to the H ions present. In general, if the solution is sufficiently dilute so that the acid is completely dissociated and the acid radical is of such a nature that at this concentration its ions have practically no poisonous action, the toxic value of the acid solution is due only to the H ions present. Now strong acids are highly dissociated in aqueous solutions, thus rendering these relatively rich in H ions. Weaker acids are not as strongly dissociated, their solutions contain less H ions, and are consequently less active. It must be borne in mind that the salt remaining undissociated is present in the solution as well as the ions. That these undissociated remainders and the anions of the acid radical also exert an effect is not to be denied, but in many cases, such as that of the Cl ions in hydrochloric acid solutions, the action is practically *nil* at the strength at which hydrochloric acid is still effective, since a solution of common salt containing as many Cl ions as the hydrochloric acid solution in question is ineffective. The same reasoning may be applied to nitrate of sodium and nitric acid, also to sodium hydroxide and common salt. In the latter case the solutions differ from each other in that the former contains OH ions, whereas the latter contains Cl ions. All solutions of bases (lyes) contain OH ions and their toxic action is due to these alone, provided that the metal or radical forming the cathion is itself harmless at the concentration used. Thus it is evident that H ions and OH ions have toxic properties. That it is the ionic condition which brings this about is shown by the fact that in the case of water where we have these constituents in practically an undissociated state, there is no toxic action.

The poisonous property of a very dilute solution is then due to the ions it contains, and if at the particular concentration in

hand only one physiologically active ion is present the effectiveness of the solution is to be attributed to that one ion. Solutions of hydrochloric, nitric and sulphuric acids are nearly completely dissociated when an equivalent in grams is dissolved in 1000 liters of water. Hence such or more dilute solutions of these acids, when chemically equivalent quantities are dissolved, ought to have the same toxic effect, the Cl, NO_3 and SO_4 ions at such dilution being harmless. That these radicals are harmless is shown by the fact that like concentrations of the sodium salts of these acids are harmless.

EXPERIMENTAL METHODS.

We have tested this point experimentally for the higher plants by ascertaining the strength of solution in which roots of the ordinary field lupine will just live. We have found that the limit for these acids is reached in case of a solution containing one equivalent in grams in 6400 liters of water. We may say, then, that one gram of hydrogen ions distributed through 6400 liters of water will give a solution in which roots of the lupine will just survive. It is entirely immaterial at this dilution whether we take hydrochloric, nitric or sulphuric acids; the toxic action of the solutions is the same, provided they contain the same amount of hydrogen ions. The molecular weight in grams, or simply one gram-molecule of acid sulphate of potassium in 6400 liters, would contain as much ionic hydrogen as a gram-molecule of hydrochloric acid, and should therefore have the same toxic effect. This has been confirmed by experiment.

It seemed best to confine our first investigations to one order of plants, and, by reason of the nature of the question under consideration, to operate with objects which by previous physiological study have become in a degree well known to botanists. It is for this reason that the seedlings of *Lupinus albus* L. were selected. This seedling is remarkable for its straight, clean radicle, the ease with which uniform specimens can be obtained, and for its great sensitiveness to solu-

tions.[10] The seeds were germinated in the usual manner. After being swelled in water they were placed in moist, loose cotton batting and set in the dark until the radicles had reached a length of from 2^{cm} to 4^{cm}, when they were ready for use.

Experiments were made with solutions contained in glass beakers of convenient size that were, of course, cleaned with the utmost care each time they were used. To support the seedling in proper position the following arrangement was used. Through a large cork fitting loosely over the beaker was thrust a glass rod which played rather tightly through it. Another and smaller piece of cork (small enough to allow ample room about it in the beaker) was likewise tightly pushed on the rod. To the circumference of this inner cork the seedlings were secured by means of glass pins, and by sliding the cork support up or down on the rod they were set into the solution at the desired depth. The large cork, by closing loosely the mouth of the beaker, allowed sufficient change of air within, at the same time preventing undue evaporation from the solution.

Since in the experiments the prime thing sought was the degree of concentration at which each solution just allowed the radicles to live, it became important to avail ourselves of all the means which would aid in deciding whether a radicle was living or dead. As Askenasy[11] has pointed out, almost the only reliable indication concerning the condition of a plant is its growth rate. Accordingly access was had to the well known method of Sachs.[12] A fine mark of India ink was made 15^{mm} from the tip of the root, a distance safely including the entire growing zone of the radicle. Thus marked, the roots were placed in the solutions, set in the dark, and again observed after a period of from fifteen to twenty-four hours. In order to deter-

[10] True, On the influence of sudden changes of turgor and of temperature on growth. Ann. of Bot. **9**: 372. 1895.

[11] Askenasy, Ueber einige Beziehungen zwischen Wachsthum und Temperatur. Ber. d. deutsch. bot. Gesellsch. **8**: 75. 1890.

[12] Sachs, Ueber das Wachsthum der Haupt- und Nebenwurzeln. Arb. d. bot. Institut Würzburg **1**: —. 1873, and Gesammelte Abhandlungen über Pflanzen-physiologie. **2**: 778. 1893.

mine the condition of the roots, the general appearance and the growth made after the beginning of the experiment were taken into account. If a much too concentrated solution was used a plainly abnormal aspect was usually found. In the acid solutions the satiny luster of the normal surface was lost and a dead-white color was observed, suggesting a condition perhaps best described by the word *coagulated.* Although difficult to describe, this condition is quickly detected by the observer, and is undubitable evidence of death. An instructive discussion of this and other *post mortem* symptoms has recently been presented by Paul Klemm.[13] The radicles killed in colored solutions, as salts of copper, iron, cobalt, etc., took on more or less decidedly the color of the medium. Some radicles after death assumed an unusual transparent appearance. This was the case with those in potassium hydroxide, and in mercuric cyanide, potassium ferro and ferricyanide, hydrocyanic acid and potassium cyanide.

Another evidence that death has taken place is seen in the flabby condition following the loss of turgor pressure. This, in the extremely dilute solutions here used, could in no case be due to the osmotic properties of the solutions, and it would be still more improbable that, after fifteen to twenty-four hours in the medium, the flabby appearance could be due to this cause. Turgor accommodation in a normal root, when placed in a solution osmotically equivalent to those here used, would take place very soon,[14] and living roots would be turgid.

Another indication of the condition of the radicles was sought in the changes in length occurring after the beginning of the experiment. In strongly toxic concentrations where death occurred very quickly, the accompanying loss of turgor left the roots shorter than at the beginning of the experiment. As the solutions were increasingly dilute but still, within the time limit of our experiments, fatal, various amounts of growth were found

[13] Paul Klemm, Desorganizationserscheinungen der Zelle. Jahrb. f. wiss. Bot. **28**: 30. 1896.

[14] True, *ibid.* 382.

to have taken place before death, sometimes nearly equaling the normal under the prevailing conditions of temperature, etc. It was thus possible from the *ante mortem* growth in a series of solutions to locate roughly the concentration limit sought.

When neither aspect nor growth rate gave plain evidence, the radicles were measured and returned to the solutions to be again observed. If between the last observation and the first, no elongation had occurred, it was inferred that the roots were dead at the time of the former inspection.

Since, as the concentration decreases, an increasingly long exposure is necessary to work fatally, it was decided to choose a period of exposure to the solutions within which the action of the same should be judged. This period was from fifteen to twenty-four hours following the introduction of the roots into the solution. Although the time limit may seem rather broad, it must be borne in mind that solutions were always diluted by one-half, and therefore with a strong time limit, we should still be far from any absolute concentration limit.[15] Individual differences in the seedlings frequently show themselves, one radicle at times being killed, another beside it surviving. In such cases, the first surviving individual indicated the concentration sought.

Usually two seedlings were placed in each concentration tested, but sometimes only one was used. When grounds for doubting the accuracy of results were present, experiments in question were repeated.

It is not to be inferred that the limits here obtained represent the greatest strength of the given substances that these radicles can endure, since a gradual increase of concentration allows a very considerable accommodation on the part of the plant to be made, and the consequent toleration of solutions that would upon immediate use have proved fatal. This was shown in several experiments in which dead roots were left for a time in the solutions. Laterals pushed out above the dead region and grew in the solutions without serious harm.

[15] P. Klemm, *ibid.*, 33 (for acids).

TABULATED DATA.

The detailed results of the most essential experiments are presented in the appended tables. At the top of each table is given its number, the substance used, and, in the second line, the date at which the radicles were set into the solutions, and the date at which the results were observed. The distance at which the mark previously mentioned was placed from the root tip was always 15^{mm}. In the first column appear the concentrations used expressed in gram-molecules or gram-equivalents per liter of the solution. The column headed "length" shows the distance between the line and the root tip, giving, therefore, after subtracting 15^{mm}, the growth made during the period indicated. If further observations and measurements were made, the dates and lengths are placed in adjacent columns. Under "remarks" are verbal indications on the condition of the radicles. Death or survival indicates the condition at the time given in column two. The number of horizontal readings under each concentration shows the number of roots employed and their individual records. For a large majority of the substances, there appears in the table the record of the last plainly fatal dilution and of all weaker solutions as far as tested. Thus the concentration limit in most cases is the second concentration in the table.

It will be noted in the concentrations not fatal, that, in general, the amount of growth increases as the concentration decreases. Since, in these experiments, external conditions were not particularly controlled, the value of the growth rates must not be overestimated and are significant only in features recurring with regularity.

Tables 1 to 5 show that the seedlings just survive in a solution that contains $\frac{1}{6400}$ gram of hydrogen ions per liter. It is evident from what has been stated before that the anions have no toxic action at this dilution, and that the poisonous action of the solutions is solely due to the hydrogen ions present, inasmuch as these various acids affect the seedlings alike.

1. Hydrochloric acid (HCl).

(Begun January 9, 8 P.M.; closed January 10, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	17.8mm	flabby, dead
. . .	19.0 "	" "
$\frac{1}{6400}$	29.0 "	appearance normal
. . .	18.5 "	tip dead

2. Hydrobromic acid (HBr).

(Begun January 11, 6 P.M.; closed January 12, 10 A.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	18.5mm	flabby, dead
. . .	18.0 "	" "
$\frac{1}{6400}$	27.5 "	apparently normal
. . .	23.5 "	flabby, dead
$\frac{1}{12800}$	28.5 "	apparently normal
. . . .	31.5 "	" "

3. Nitric acid (HNO_3).

(Begun January 11, 5 P.M.; closed January 12, 10 A.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	17.5mm	flabby, dead
. . .	17.0 "	" "
$\frac{1}{6400}$	28.0 "	apparently normal
. . .	25.0 "	" "
$\frac{1}{12800}$	30.5 "	" "
. . . .	34.0 "	" "

4. Sulfuric acid (H_2SO_4).

(Begun January 9, 9 P.M.; closed January 10, 4 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	19.0mm	flabby, dead
. . .	17.5 "	" "
$\frac{1}{6400}$	23.0 "	" "
. . .	27.5 "	apparently normal
$\frac{1}{12800}$	28.0 "	" "
. . . .	27.0 "	" "

5. Acid-potassium sulfate ($KHSO_4$).

(Begun January 10, 6 P.M.; closed January 11, 1 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	15.5mm	flabby, dead
$\frac{1}{6400}$	30.5 "	apparently normal
. . .	32.0 "	" "
$\frac{1}{12800}$	24.0 "	" "

6. Hydrochloric acid. March 7, 10 A.M.

(Concentration: $\frac{1}{3200}$ gm. mol. per liter.)

No.	March 7, 2 P.M. 20° C.		March 7, 8 P.M. 19° C.	
1	18.0mm	3.0mm	17.6mm	flabby
2	18.5 "	3.5 "	19.0 "	"
3	18.5 "	3.5 "	18.5 "	"
4	19.5 "	4.5 "	19.5 "	"
	Av. growth per hr. 0.91mm		All dead.	

7. Hydrochloric acid. March 7, 10 A.M.

(Concentration: $\frac{1}{6400}$ gm. mol. per liter.)

No.	March 7, 2 P.M. 20° C.		March 7, 8 P.M. 19° C.		March 8, 11.30 A.M. 25° C.	
1	19.5mm	4.5mm	23.0mm	3.5mm	34.0mm	11.0mm
2	18.5 "	3.5 "	20.5 "	2.0 "	22.5 "	2.5 "
3	19.5 "	4.5 "	22.0 "	2.5 "	28.0 "	6.0 "
4	19.0 "	4.0 "	22.5 "	3.5 "	34.0 "	11.5 "
	Av. growth per hr. 1.03mm		Av. growth per hr. 0.5mm		Av. growth per hr. 0.2mm	

It will be noticed, on inspecting tables 1 to 5, that in the lowest fatal dilution, a growth prior to death of from 5mm to 10mm usually occurred. This raised the question whether, in case of the acids the hydrogen ions might not act catalytically and hasten the chemical processes of the cells and possibly also the growth of the radicle. Experiments with hydrochloric acid

have thus far yielded entirely negative results. Tables 6 to 11 give the record of these experiments, but more work along this line is needed. The first column simply numbers the experiment; the remainder give the results at the times and temperatures named.

8. DISTILLED WATER (Control). MARCH 7, 10 A.M.

March 7, 2 P.M. 20° C.		March 7, 8 P.M. 19° C.		March 8, 11:30 P.M. 25° C.	
19.0mm	4.0mm	23.0mm	4.0mm	31.0mm	8.0mm
21.5 "	6.5 "	26.5 "	5.0 "	36.5 "	10.0 "
21.0 "	6.0 "	28.5 "	7.5 "	43.0 "	14.5 "
21.0 "	6.0 "	26.0 "	5.0 "	36.0 "	10.0 "
Av. growth per hr. 1.5mm		Av. growth per hr. 0.87mm		Av. growth per hr. 0.69mm	

9. DISTILLED WATER (Control). MARCH 14, 11 A.M.

March 14, 3 P.M. 20° C.		March 15, 10 A.M. 22° C.		March 16, 9:30 A.M. 25° C.		March 17, 11 A.M. 23° C.		March 19, 3 P.M. 20° C.	
18.5mm	3.5mm	34.5mm	16.0mm	52.0mm	17.5mm	66.0mm	14.0mm	86.5mm	20.5mm
17.5 "	2.5 "	34.0 "	16.5 "	54.5 "	20.5 "	71.0 "	16.5 "	96.0 "	25.0 "
18.5 "	3.5 "	36.0 "	17.5 "	56.0 "	20.0 "	76.5 "	20.5 "	104.0 "	27.5 "
18.5 "	3.5 "	28.0 "	9.5 "	45.0 "	17.0 "	59.0 "	14.0 "	87.0 "	28.0 "
Av. growth per hr. 0.81mm		Av. growth per hr. 0.8mm		Av. growth per hr. 0.83mm		Av. growth per hr. 0.63mm		Av. growth per hr. 0.57mm	

10. HYDROCHLORIC ACID. MARCH 14, 11 A.M.

(Concentration: $\frac{1}{12800}$ gm. mol. per liter.)

March 14, 3 P.M. 20° C.		March 15, 10 A.M. 22° C.		March 16, 9:30 A.M. 25° C.		March 17, 11 A.M. 23° C.		March 19, 3 P.M. 20° C.	
17.0mm	2.0mm	26.0mm	9.0mm	43.5mm	17.5mm	65.0mm	21.5mm	87.5mm	22.5mm
18.0 "	3.0 "	30.0 "	12.0 "	45.0 "	15.0 "	60.0 "	15.0 "	77.5 "	17.5 "
18.5 "	3.5 "	30.0 "	11.5 "	39.5 "	9.5 "	52.0 "	12.5 "	71.0 "	19.0 "
19.0 "	4.0 "	33.0 "	14.0 "	49.0 "	16.0 "	69.0 "	20.0 "	90.0 "	21.0 "
Av. growth per hr. 0.78mm		Av. growth per hr. 0.61mm		Av. growth per hr. 0.64mm		Av. growth per hr. 0.68mm		Av. growth per hr. 0.39mm	

11. Hydrochloric acid. March 14, 11 A.M.

(Concentration: $\frac{1}{2500}$ gm. mol. per liter.)

March 14, 3 P.M. 20° C.		March 15, 10 A.M. 22° C.		March 16, 9:30 A.M. 25° C.		March 17, 11 A.M. 23° C.		March 19, 3 P.M. 20° C.	
17.0mm	2.0mm	29.0mm	12.0mm	41.0mm	12.0mm	51.5mm	10.5mm	72.0mm	20.5mm
18.5 "	3.5 "	32.0 "	13.5 "	50.0 "	18.0 "	66.0 "	16.0 "	94.5 "	28.5 "
18.5 "	3.5 "	29.0 "	10.5 "	39.0 "	10.0 "	50.0 "	11.0 "	72.0 "	22.0 "
17.5 "	2.5 "	24.0 "	6.5 "	31.5 "	7.5 "	41.0 "	9.5 "	57.0 "	16.0 "
Av. growth per hr. 0.72mm		Av. growth per hr. 0.56mm		Av. growth per hr. 0.50mm		Av. growth per hr. 0.52mm		Av. growth per hr. 0.35mm	

12. Potassium hydroxide (KOH).

(Begun January 9, 9 P.M., closed January 10, 4 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{200}$	16.5mm	rather transparent—alive(?)
. . .	17.5 "	" " " (?)
$\frac{1}{400}$	27.0 "	apparently normal—alive
. . .	28.0 "	" " "
$\frac{1}{800}$	36.0 "	" " "
$\frac{1}{1600}$	32.0 "	" " "
$\frac{1}{3200}$	42.0 "	" " "
$\frac{1}{6400}$	37.5 "	" " "

The above table for potassium hydroxide shows that the seedlings plainly live when the solution contains $\frac{1}{400}$ gm. mol. per liter. The potassium hydroxide used was free from carbon-dioxide at the beginning of the experiment, but of course the solution absorbed the carbon-dioxide given off by the plant as well as some from the air during the progress of the experiment, so that the hydroxyl ion is to be regarded as somewhat more poisonous than the above figures would indicate.

Tables 13 to 15 show that in case of the three copper salts investigated, the strength of the solution in which the seedlings will just survive is $\frac{1}{51200}$ gm. mol. per liter. As these salts can be regarded as practically completely dissociated[16] at this great dilution, and as they act alike, it is evident that this figure gives

[16] Compare the tables of the electrical conductivity of copper salts collected by Ostwald in his Lehrbuch d. allgem. Chem., 2:770 [ed. 2]. The electrical conductivity of

the concentration at which the copper ions in the solution are insufficient to kill the beans.

13. Copper sulfate ($CuSO_4$).

(Begun February 26, 4 P.M.; closed February 27, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25600}$	16.0mm	discolored, dead
. . . .	16.5 "	" "
$\frac{1}{51200}$	21.0 "	alive
. . . .	22.0 "	alive (?), tip slightly discolored
$\frac{1}{102400}$	32.0 "	alive
$\frac{1}{204800}$	28.0 "	"

14. Copper chloride ($CuCl_2$).

(Begun February 26, 4 P.M.; closed February 27, 1 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25600}$	16.2mm	dead
. . . .	17.0 "	"
$\frac{1}{51200}$	19.0 "	alive (?), tip slightly darkened
. . . .	18.0 "	alive
$\frac{1}{102400}$	21.0 "	"
$\frac{1}{204800}$	26.5 "	"

15. Copper acetate. $-Cu(C_2H_3O_2)_2$.

(Begun February 26, 5 P.M.; closed February 27, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25600}$	16.0mm	dead
. . . .	16.0 "	"
$\frac{1}{51200}$	23.0 "	alive
. . . .	22.0 "	"
$\frac{1}{102400}$	21.0 "	"
. . . .	21.0 "	"
$\frac{1}{204800}$	28.0 "	"
. . . .	26.0 "	"

solutions of the compounds used in the above tables 1 to 6, as well as of most of the inorganic substances mentioned in this paper, are also to be found in Ostwald's Lehrbuch, 2:722–772.

16. $1CuSO_4 + 1C_{12}H_{22}O_{11} + 3KOH$.

200 cc. $CuSO_4$, $\frac{1}{200}$ gm. mol. per liter; 200 cc. sugar, $\frac{1}{100}$ gm. mol. per liter; 3 cc. normal KOH.

(Begun December 5, 8 P.M.)

Concentration gm. mol. per liter	Length Dec. 6, 9 A.M.	Length Dec. 9, 9 A.M.	Remarks
$\frac{1}{400}$	18.0mm	22.0mm	living
...	19.0 "	21.0 "	"

(Slight precipitate, probably due to contact with air and CO_2 excreted from roots. Concentration given based on $CuSO_4$ content.)

17. $1CuSO_4 + 1C_{12}H_{22}O_{11} + Ca(OH)_2$.

200 cc. $CuSO_4$, $\frac{1}{200}$ gm. mol. per liter; 400 cc. sugar, $\frac{1}{100}$ gm. mol. per liter; 106.4 cc. $Ca(OH)_2$ (saturated solution).

(Begun December 5, 8 P.M.)

Concentration gm. mol. per liter.	Length Dec. 6, 9 A.M.	Length Dec. 9, 9 A.M.	Remarks
0.00142	19.5mm	46.0mm	alive
	19.5 "	48.5 "	"
	18.5 "	46.5 "	"

(Solution deep blue. A slight precipitate formed on standing. Concentration given based on $CuSO_4$ content.)

It has been shown[17] recently that in Fehling's solution and allied solutions containing copper the copper does not exist as an ion by itself, but as a part of a complex ion formed with the organic substance present. Such complex ions, according to our theory, we should naturally expect to have a quite different toxic action from that shown by copper ions. Experiment has verified this. In tables 16 and 17 are given the results obtained with solutions of the character just mentioned. The composition of the solution is indicated in each table. Cane sugar was used instead of Rochelle salts in order to avoid getting too many salts into the solution. An excess of caustic alkali was also avoided for it would have introduced hydroxyl ions into the solution which are of themselves poisonous. The beans grow in this

[17] Kahlenberg, Zeitschr. f. physik. Chem. 8: 587, 608–613.

case in solutions that are perfectly blue in color and contain $\frac{1}{400}$ gram atom copper per liter. The enormous contrast that this result presents with that obtained in the experiments in which the copper exists in the solution as ion (tables 14 and 15) is apparent and shows that the copper ion is far more poisonous than the complex ion which contains copper.

18. Ferric chloride ($FeCl_3$).

(Begun December 5, 9 P.M.)

Concentration gm. per liter	Length Dec. 6, 9 A.M.	Length Dec. 9, 9 A.M.	Remarks
Fe, 0.0477 Cl, 0.0906	15.0mm		dead, mahogany red
	15.7 "		" " "
Fe, 0.00500 Cl, 0.00930	19.7 "		turgor gone, dead
	20.5 "		" " "
Fe, 0.00250 Cl, 0.00477	21.5 "	21.0mm	dead
	21.5 "	21.5 "	"

(Concentration allowing growth not reached. Probably found at next dilution with half the Fe and Cl content of the last in the table.)

19. Dialyzed iron ($FeCl_3$).

(Begun November 21, 5 P.M.)

Concentration	Length Nov. 22, 9 A.M.	Length Dec. 2, 9 A.M.	Remarks
Fe, 0.0095555% Cl, 0.0093	18.5mm		dead, laterals form in solution
	17.5 "		" " " " "
Fe, 0.00477% Cl, 0.00047	23.5 "	51.5mm	living, surface reddish
	24.0 "	62.0 "	" " "
	26.0 "	51.5 "	" " "

From table 18, giving the results obtained with ferric chloride, it is evident that ferric ions have a quite strong toxic action. It is known that ferric chloride splits up hydrolytically in dilute solutions, which makes this case somewhat complicated. The main object, however, was to compare the action of the ferric

chloride solution with that of a solution of dialyzed iron,[18] which contains no ferric ions inasmuch as potassium ferrocyanide (which is a test for ferric ions) produces no precipitate in the solution. The absence of chlorine ions in the solution is shown by the fact that silver nitrate produces no turbidity in such a solution. The tables show conclusively that ferric ions are much more poisonous than are the complex ions containing ferric iron in the dialyzed iron solution.

20. FERROUS SULFATE ($FeSO_4$).

(Begun March 7, 12 M.; closed March 8, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{12800}$	18.0mm	dead, purplish spotted
.....	19.0 "	" " "
$\frac{1}{25600}$	24.0 "	alive, tip somewhat discolored
.....	22.0 "	dead, discolored
$\frac{1}{51200}$	34.0 "	alive, root-tip dead
.....	29.0 "	" " "

Table 20 shows that for ferrous ions the concentration limit at which the seedlings will just survive is $\frac{1}{51200}$ gram ion per liter. The same limit obtains in case of the nickel and cobalt ions (tables 21 to 24). Two nickel salts and also two cobalt salts were tested in order to show again that it is immaterial at this dilution whether the nitrates or the sulphates are used; in other words, that the toxic action of the solutions is solely due to the ions of the metals present.

21. NICKEL SULFATE ($NiSO_4$).

(Begun March 7, 11 A.M.; closed March 8, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25600}$	19.0mm	dead
.. .	22.0 "	"
$\frac{1}{51200}$	33.5 "	alive
.....	31.0 "	"

[18] The solution of dialyzed iron used in the experiments of table 19 was prepared according to the directions given in the British pharmacopœia.

22. NICKELOUS NITRATE ($Ni(NO_3)_2$).

(Begun March 20, 4 P.M.)

Concentration gm. mol. per liter	Length March 21, 10 A.M.	Length March 23, 3 P.M.	Remarks
$\frac{1}{256}$	26.0mm	26.5mm	dead
. . . .	20.0 "	20.0 "	"
$\frac{1}{512}$	28.0 "	28.0 "	"
. . . .	37.0 "	45.0 "	" liv. Mar. 21

23. COBALTOUS SULFATE ($CoSO_4$).

(Begun March 20, 3 P.M.)

Concentration gm. mol. per liter	Length March 21, 10 A.M.	Length March 23, 3 P.M.	Remarks
$\frac{1}{128}$	20.0mm	19.0mm	dead
. . . .	22.0 "	22.0 "	"
$\frac{1}{256}$	23.0 "	27.5 "	" liv. Mar. 21
. . . .	27.0 "	33.0 "	" " " "
$\frac{1}{512}$	35.0 "	61.5 "	alive
. . . .	35.0 "	46.0 "	dead, liv. Mar. 21

24. COBALTOUS NITRATE ($Co(NO_3)_2$).

(Begun November 23, 5 P.M.; closed March 24, 3 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{256}$	38.0mm	alive
. . . .	15.5 "	dead
$\frac{1}{512}$	40.0 "	alive
. . . .	28.0 "	"

That cobalt, nickel and iron in the ionic condition thus have the same toxic effect would tend to arouse in the mind of the chemist the question whether this is not connected with the fact that these metals have nearly the same atomic weight. Whether there is a definite relation between the toxic effects of the ions of the metals and the atomic weights of the latter, in other words whether the periodic law finds application here, is a question that can be answered only after more experimental data have been gathered.

25. Cadmium nitrate ($Cd(NO_3)_2$).

(Begun March 23, 5 P.M.)

Concentration gm. mol. per liter	Length March 24, 3 P.M.	Length March 25, 3 P.M.	Remarks
$\frac{1}{1024}$	20.0mm	19.5mm	dead
. . . . .	21.0 "	20.5 "	"
$\frac{1}{2048}$	29.0 "		alive
. . . . .	24.0 "		"

This table shows that cadmium ions are exceedingly poisonous in character.

26. Potassium cyanide (KCn).

(Begun February 3, 4 P.M.; closed February 4, 4 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{6400}$	17.5mm	alive, near boundary
. . .	18.0 "	" " "
$\frac{1}{12800}$	20.5 "	"
. . . .	21.0 "	"
$\frac{1}{25600}$	25.0 "	"
. . . .	18.0 "	"
$\frac{1}{51200}$	30.0 "	"
$\frac{1}{102400}$	26.5 "	"
$\frac{1}{204800}$	33.5 "	"

27. Potassium ferrocyanide (K_4FeCn_6).

(Begun December 15, 7 P.M.)

Concentration gm. mol. per liter	Length Dec. 14, 12 M.	Length Dec. 17, 9 A.M.	Remarks
$\frac{1}{100}$	17.0mm		dead, transp'rent
$\frac{1}{200}$	17.0 "	21.5mm	living, appearance normal
. . .	16.0 "	17.5 "	" " "
$\frac{1}{400}$	19.5 "	19.0 "	dead
. . .	17.5 "	18.0 "	living, ap. nor.
$\frac{1}{800}$	20.0 "	21.5 "	" " "
. . .	20.5 "	23.5 "	" " "
$\frac{1}{1600}$	24.5 "	30.0 "	" " "
. . . .	24.5 "	33.5 "	" " "

THE UNIVERSITY LIBRARIES OF GEORGIA

28. POTASSIUM FERRICYANIDE (K_3FeCn_6).

(Begun December 13, 8 P.M.)

Concentration gm. mol. per liter	Length Dec. 14, 1 P.M.	Length Dec. 17, 10 A.M.	Remarks
$\frac{1}{200}$	18.5mm	18.5mm	alive, boundary
. . .	19.0 "	19.0 "	" "
$\frac{1}{400}$	20.5 "	26.0 "	" "
. . .	20.0 "	20.0 "	" "
$\frac{1}{800}$	27.5 "	41.0 "	" "
. . .	25.0 "	37.0 "	" "
$\frac{1}{1600}$	27.5 "	52.0 "	" "
. . . .	25.5 "	45.0 "	" "

Table 26 gives the concentration of cyanogen ions that the lupines can bear; it is about the same as that for hydrogen ions. In potassium ferrocyanide and potassium ferricyanide the iron and the cyanogen radical form complex ions[19] which, as tables 27 and 28 show, have the same toxic effect. This is much less, however, than in the case where iron exists in the solution as an ion by itself or where cyanogen ions as such are present in the solution.

Experiments were also performed with a solution of mercuric chloride. The detailed results of these have unfortunately been mislaid, but the concentration of this solution that the lupines can bear was found to be $\frac{1}{1280}$ gm. equivalent per liter. Mercuric chloride is a compound that is but slightly dissociated at concentrations at which it is ordinarily used in laboratories; at the above mentioned concentration, however, the dissociation must have advanced to a considerable degree.

From a solution of mercuric chloride mercuric oxide can be precipitated by means of potassium hydroxide. If, however, a considerable amount of dextrine be first added to the mercuric chloride solution caustic alkali no longer precipitates mercuric oxide. The solution remains clear, which shows that mercuric ions no longer are present and that the mercury has united with the dextrine to form a complex ion. The latter ions are not as poisonous as mercuric ions, as is apparent from table 29.

[19] These ions are $Fe'' CN_6$ and $Fe''' CN_6$ respectively.

29. MERCURIC CHLORIDE + DEXTRINE + CAUSTIC POTASH.

The detailed record having been mislaid, the end results are here given.

(Concentrations calculated on the mercuric chloride.)

Concentration gm. mol. per liter	Result
$\frac{1}{200}$	died
$\frac{1}{400}$	"
$\frac{1}{800}$	"
$\frac{1}{1600}$	"
$\frac{1}{3200}$	"
$\frac{1}{6400}$	lived
$\frac{1}{12800}$	"

30. MERCURIC CYANIDE ($HgCN_2$).

(Begun February 25, 5 P.M.; closed February 26, 3 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25600}$	24.0mm	transparent in growing parts, dead
.....	28.5 "	" " " " "
$\frac{1}{51200}$	28.5 "	dead
.....	30.0 "	"
$\frac{1}{102400}$	45.0 "	alive
$\frac{1}{104800}$	44.0 "	"
$\frac{1}{409600}$	45.0 "	"
$\frac{1}{819200}$	44.0 "	"
.....	46.0 "	"

Mercuric cyanide solutions possess no measurable electrical conductivity. This compound is then practically not dissociated in its solutions. Its toxic effect is consequently due to the undissociated salt ($HgCN_2$) in the solution. The fact that the roots can bear only $\frac{1}{102400}$ gm. mol. per liter of this substance speaks for its pronounced poisonous character.

In tables 31 and 32 are the results obtained with solutions of silver nitrate and silver sulfate respectively. That these solutions behave alike toward the lupines is again evidence that it is only the silver ions they contain that are active. Their extremely poisonous character will be noted. They are the most poisonous ions that we have investigated.

31. SILVER NITRATE ($AgNO_3$).

(Begun February 3, 6 P.M.; closed February 4, 10 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{204800}$	17.5mm	dead
$\frac{1}{409600}$	20.0 "	alive (?)
$\frac{1}{819200}$	22.0 "	alive
. . . .	17.0 "	"
$\frac{1}{1638400}$	22.0 "	"

32. SILVER SULFATE (Ag_2SO_4).

(Begun March 23, 5 P.M.)

Concentration gm.equiv.per liter	Length March 24, 3 P.M.	Length March 25, 3 P.M.	Remarks
$\frac{1}{204800}$	21.0mm		discolored, dead
. . . .	16.0 "		" "
$\frac{1}{409600}$	23.0 "	22.0mm	dead
. . . .	25.0 "	26.0 "	" (?)
$\frac{1}{819200}$	25.0 "		alive, distorted
. . . .	29.0 "		" "

33. SILVER NITRATE ($AgNO_3$) $\frac{1}{10}$ gm. mol. per liter, 10cc.
POTASSIUM CYANIDE (KCN) $\frac{1}{10}$ " " " " 30cc.

(Concentrations estimated on basis of Ag present.)

(Begun April 14, 4 P.M.)

Concentration gm. mol. per liter	Length April 15, 4 P.M.	Length April 17, 4 P.M.	Remarks
$\frac{1}{6400}$	22.0mm	22.0mm	dead, discolored
. . . .	21.0 "	22.0 "	" "
$\frac{1}{12800}$	22.0 "	23.0 "	" "
. . . .	21.0 "	22.0 "	" "
$\frac{1}{25600}$	20.0 "	20.0 "	" "
. . . .	24.0 "	26.5 "	alive April 15
$\frac{1}{51200}$	25.0 "	27.0 "	" "
. . . .	26.0 "	31.0 "	" "
$\frac{1}{102400}$	26.5 "	33.5 "	living
. . . .	29.5 "	39.0 "	"
$\frac{1}{204800}$	32.0 "	41.5 "	"
. . . .	31.0 "	51.5 "	"
$\frac{1}{409600}$	35.0 "	61.0 "	"

34. SILVER NITRATE ($AgNO_3$) $\frac{1}{10}$ gm. mol. per liter, 10cc.
POTASSIUM CYANIDE (KCN) $\frac{1}{10}$ " " " " 27.5cc.

(Concentrations based on Ag present.)

(Begun April 14, 5 P.M.)

Concentration gm. mol. per liter	Length April 15, 4 P.M.	Length April 17, 4 P.M.	Remarks
$\frac{1}{12800}$	21.0mm	21.0mm	dead
. . . .	20.0 "	20.0 "	"
$\frac{1}{25600}$	20.0 "	21.5 "	" alive Apr. 15
. . . .	24.0 "	26.0 "	" " "
$\frac{1}{51200}$	22.5 "	25.0 "	living
. . . .	24.5 "	26.0 "	"
$\frac{1}{102400}$	24.0 "	36.5 "	"
. . . .	23.5 "	27.0 "	"
$\frac{1}{204800}$	31.0 "	46.0 "	"
. . . .	31.0 "	30.0 "	dead
$\frac{1}{409600}$	31.0 "	55.0 "	living

When silver nitrate in solution is treated with potassium cyanide solution, a precipitate of silver cyanide is formed, which upon further addition of potassium cyanide redissolves. The solution of silver cyanide in cyanide of potassium is due to the formation of potassium silver cyanide, $KAgCN_2$, which in aqueous solutions dissociates into the ions K^+ and $AgCN_2^-$. The latter are very stable, and we should naturally expect from the theory that they have a different toxic action from the Ag ions. This is confirmed by experiment. The results are given in tables 33 and 34 which show that the ions $AgCN_2^-$ are far less poisonous than silver ions.[20]

A few other inorganic acids will now be considered, the action of which is not quite as readily explained as that of the acids mentioned in tables 1 to 4. Hydrocyanic acid is practically not dissociated in aqueous solutions, for its electrical conductivity is almost *nil*. The toxic action of this acid must be due, then, to the undissociated HCN present in the solution. Table 35 shows that the lupines will bear $\frac{1}{12800}$ gm. mol. per liter of this acid.

[20] Compare iron and the potassium ferro- and ferricyanides as given above.

Although phosphoric acid is a tribasic acid, the electrical conductivity of its solution shows that it splits up chiefly into the ions H^+ and $H_2 Po_4^-$,[21] and consequently we should expect a solution containing phosphoric acid (made up molecularly) to show the same concentration at which the plants will grow in it as a solution of hydrochloric acid for instance, for the content of hydrogen ions is the same in both cases. Experiment verifies this as table 35 shows.

[21] See Ostwald's Lehrbuch, *loc. cit.*

35. HYDROCYANIC ACID (HCN).

(Begun March 2, 4 P.M.)

Concentration gm. mol. per liter	Length March 3, 5 P.M.	Length March 4, 3 P.M.	Remarks
$\frac{1}{6400}$	17.0mm		dead
....	16.5 "		"
$\frac{1}{12800}$	17.0 "	17.0mm	"
....	21.5 "	25.5 "	alive
$\frac{1}{25600}$	21.5 "		"
....	21.0 "		"
$\frac{1}{51200}$	23.5 "		"
....	39.5 "		"

36. PHOSPHORIC ACID (H_3PO_4).

(Begun January 31, 4 P.M.; closed February 1, 1 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	17.0mm	flabby, dead
....	19.5 "	" "
$\frac{1}{6400}$	33.5 "	apparently normal
...	28.5 "	" "
$\frac{1}{12800}$	27.0 "	" "
....	21.0 "	" "

Table 36 shows the toxic effect of a solution of chromic acid. This is a weak acid and is probably not completely dissociated at the concentration at which the roots survive in it. Whether the ion $^-Cr_2O_7^-$ is harmless at this concentration can of course only

be settled by testing a solution of potassium bichromate or sodium bichromate, in which cases the salts are to a high degree dissociated. The cathions are harmless, and consequently the concentration limit for the ion Cr_2O_7 can be found.

37. Chromic acid ($H_2Cr_2O_7$).[22]

(Begun February 1, 5 P.M.)

Concentration gm. mol. per liter	Length February 2, 3 P.M.	Length February 3, 11 A.M.	Remarks
$\frac{1}{3200}$	17.0mm		dead
....	17.5 "		"
$\frac{1}{6400}$	22.0 "	27.0mm	alive
....	28.0 "	34.5 "	"
$\frac{1}{12800}$	25.0 "		"
....	18.0 "		"

38. Boric acid.

(Begun February 3, 1 P.M.; closed February 4, 10 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{2}{25}$	18.0mm	dead
..	16.0 "	"
$\frac{1}{25}$	16.5 "	"
..	18.0 "	alive (?)
$\frac{1}{50}$	17.5 "	living (?)
..	21.5 "	"
$\frac{1}{100}$	28.5 "	apparently normal
...	28.0 "	" "
$\frac{1}{200}$	39.0 "	" "
...	35.0 "	" "
$\frac{1}{400}$	32.0 "	" "
$\frac{1}{800}$	29.5 "	" "
...	41.5 "	" "
$\frac{1}{1600}$	29.5 "	" "
....	22.5 "	" "
$\frac{1}{3200}$	28.0 "	" "
....	35.0 "	" "
$\frac{1}{6400}$	30.5 "	" "
....	39.5 "	" "

Boric acid solutions are poor conductors of electricity. The acid is then but very slightly dissociated. Experiments on this acid seemed desirable since it is used so much as an antiseptic.

[22] See Ostwald, Zeitschr. f. physik. Chem. **2**:78.

39. MANNITE.

(Begun February 3, 1 P.M.; closed February 4, 10 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{2}{25}$	26.5mm	alive
. .	34.5 "	"
$\frac{1}{25}$	32.5 "	"
. .	31.5 "	"
$\frac{1}{50}$	27.0 "	"
$\frac{1}{100}$	26.0 "	"
$\frac{1}{200}$	44.0 "	"
$\frac{1}{400}$	37.0 "	"

40. BORO-MANNITIC ACID.

(Begun February 3, 1 P.M.; closed February 4, 10 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25}$	15.5mm	dead
. .	16.5 "	"
$\frac{1}{50}$	18.5 "	" (?)
. .	18.0 "	" (?)
$\frac{1}{100}$	22.0 "	alive
$\frac{1}{200}$	32.0 "	"
$\frac{1}{400}$	34.0 "	"
$\frac{1}{800}$	35.0 "	"
$\frac{1}{1600}$	34.0 "	"

41. BORIC ACID AND CANE SUGAR.

(Begun February 3, 5 P.M.; closed February 4, 10 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{25}$	16.5mm	alive ?
. .	17.0 "	" !
$\frac{1}{50}$	19.0 "	" !
. .	19.0 "	" !
$\frac{1}{100}$	22.5 "	"
. . .	20.0 "	"

Table 38 shows the results that were obtained. From these the weak action of the acid is apparent. Mannite has no toxic action on the seedlings, as is shown by table 39; however, it is well known that when boric acid and mannite solutions are

mixed the resulting solution has an acid reaction caused by the presence of hydrogen ions that have resulted from the electrolytic dissociation of a complex boro-mannitic acid that has been formed in the solution. We should, therefore, expect such a solution of boric acid mannite, containing more hydrogen ions than a solution which contains the same amount of boric acid but without the mannite, to have a greater toxic effect than the latter. Table 40 shows results that confirm this. Cane sugar and boric acid do not form a complex acid with each other, consequently no increase of concentration of hydrogen ions is caused by mixing them, and of course we should expect the mixture to have the same toxic action as an equivalent solution of boric acid without addition of cane sugar. A comparison of tables 38 and 41 shows that this is in accord with experimental facts.

In his extensive work on the affinity of constants of organic acids, Ostwald[23] determined the electrical conductivity of a large number of acids, thus giving us a knowledge of the degree to which these acids are dissociated in their solutions. The most dilute solutions with which he worked contained 1 gm equivalent in 1024 liters. Only a relatively small number of the acids he investigated are highly dissociated at this concentration. In investigating the toxic effect of organic acids upon the lupines, it was found that the concentrations in which the plants would just survive are less than 1 gm. equivalent in 1024 liters, so that it is impossible from Ostwald's determinations to tell to what degree the acids are dissociated at these higher dilutions. In only a few of the cases investigated can the acid be considered as practically completely dissociated, as was done in case of the strong mineral acids, so that the effect of the undissociated acid present cannot be left out of account. This anion, too, in many cases no doubt exerts a distinct poisonous action of its own.

Typical acids from the fatty series and from the aromatic series were investigated. The results are given in the tables that follow.

[23] Zeitschr. f. physik. Chem. 3:170, 241, 369.

42. FORMIC ACID.

(Begun January 11, 8 P.M.; closed January 12, 11 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	21.5mm	flabby, dead
. . .	19.0 "	" "
$\frac{1}{6400}$	28.0 "	apparently normal
. . . .	27.5 "	" "
$\frac{1}{12800}$	34.0 "	" "
. . . . .	26.0 "	" "

43. ACETIC ACID.*

(Begun January 11, 9 P.M.; closed January 12, 11 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	18.5mm	dead
. . .	18.6 "	"
$\frac{1}{1600}$	25.0 "	alive
$\frac{1}{3200}$	31.5 "	"
$\frac{1}{6400}$	30.5 "	"
$\frac{1}{12800}$	30.0 "	"

44. PROPIONIC ACID.†

(Begun January 11, 10 P.M.; closed January 12, 11 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{1600}$	18.5mm	dead
$\frac{1}{3200}$	28.5 "	alive
$\frac{1}{6400}$	28.0 "	"
$\frac{1}{12800}$	34.0 "	"

45. BUTYRIC ACID.

(Begun January 14, 10 P.M.)

Concentration gm. mol. per liter	Length Jan'y 15, 10 A.M.	Length Jan'y 15, 6 P.M.	Remarks
$\frac{1}{800}$	18.0mm	18.0mm	dead
. . .	18.0 "		
$\frac{1}{1600}$	18.5 "	18.5 "	dead
. . .	18.5 "	18.5 "	"
$\frac{1}{3200}$	20.0 "	23.0 "	alive

* Repeated with same boundary.

† Repeated with same result.

46. VALERIANIC ACID.

(Begun January 15, 4 P.M.; closed January 16, 3 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{1600}$	19.0mm	dead
. . .	16.0 "	"
$\frac{1}{3200}$	28.0 "	alive
. . .	28.5 "	"

From table 42 it appears that the lupines survive in a solution of formic acid containing $\frac{1}{6400}$ gm. mol. per liter, the same concentration as in the case of the strong mineral acids. According to Ostwald's determination, formic acid is dissociated to the extent of 35.85 per cent. when one gm. mol. is present in 1024 liters. At 6400 it would be much more highly dissociated. From the result it would appear that dissociation is nearly complete at this high dilution, for the critical concentration is that obtained in case of the strong mineral acids. Whether this is true or not can be better decided after the effect of sodium formate on the seedlings has been studied. Table 43 shows that the radicles can bear much more acetic acid than formic. Acetic acid is not as strongly dissociated. Propionic, butyric and valerianic acids (tables 44 to 46) show the same critical concentration, $\frac{1}{3200}$ gm. mol. per liter. Ostwald's measurements show that these acids at 1024 are dissociated to approximately the same degree; and, as they are closely allied chemically, one would expect them to have the same effect on the roots. The content of hydrogen ions of the solutions is nearly the same, and the undissociated parts together with the anions would have about the same effect. Acetic acid is a little more strongly dissociated than the last named acids; the fact that nevertheless the seedlings will bear a greater concentration shows that it is not merely the contact of hydrogen ions that comes into consideration here, but that the action of the undissociated acid and the anions makes itself felt.

Glycollic acid is somewhat more strongly dissociated than

lactic acid, so a greater toxic effect would be expected from the former than from the latter considering only the concentration of the hydrogen ions. A comparison of tables 47 and 48 shows that glycollic acid does have a greater poisonous action.

47. GLYCOLLIC ACID.

(Begun January 28, 5 P.M.; closed January 29, 9 A.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	19.0mm	dead
. . .	19.5 "	"
$\frac{1}{6400}$	22.0 "	alive
. . .	27.5 "	"

48. LACTIC ACID.

(Begun January 28, 6 P.M.)

Concentration gm. mol. per liter	Length Jan'y 29, 9 A.M.	Length Jan'y 31, 4 P.M.	Remarks
$\frac{1}{1600}$	18.0mm		flabby, dead
. . .	17.0 "		" "
$\frac{1}{3200}$	21.0 "		" "
. . .	22.5 "	35.0mm	alive
$\frac{1}{6400}$	26.5 "		"
. . .	22.5 "		"
$\frac{1}{12800}$	29.0 "		"

The results obtained from the three chlor-acetic acids are given in tables 49 to 51. At the concentration in which the lupines survive these acids are all practically completely dissociated. The mono- and di-chlor-acetic acids yield the critical concentration for hydrogen ions, namely, $\frac{1}{6400}$ gm. mol. per liter. Tri-chlor-acetic acid as well as mono-brom-acetic acid still kill the seedlings at this concentration. This fact shows that at least in the latter cases the anions have a distinct toxic effect of their own, which can of course be determined by investigation of the sodium salts of the acids in question. That amido-propionic acid (table 53) has no poisonous action at the concentration

tested is easily explained by the fact that the acid forms an inner salt and so does not yield hydrogen ions when dissolved in water.

49. MONO-CHLOR-ACETIC ACID.

(Begun January 20, 8 P.M.; closed January 21, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	17.0mm	flabby, dead
. . .	18.0 "	" "
$\frac{1}{6400}$	25.5 "	apparently normal
. . .	26.0 "	" "
$\frac{1}{12800}$	22.0 "	" "
. . . .	24.5 "	" "

50. DI-CHLOR-ACETIC ACID.

(Begun January 20, 9 P.M.; closed January 21, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	17.0mm	flabby, dead
. . . .	16.0 "	" "
$\frac{1}{6400}$	22.0 "	dead (?)
. . . .	22.0 "	alive!
$\frac{1}{12800}$	24.0 "	apparently normal
. . . . .	25.0 "	" "

51. TRI-CHLOR-ACETIC ACID.

(Begun January 20, 9 P.M.; closed January 21, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{6400}$	18.5mm	turgor gone, dead
. . . .	19.0 "	" " "
$\frac{1}{12800}$	23.5 "	apparently normal
. . . . .	27.5 "	" "

52. MONO-BROM-ACETIC ACID.

(Begun January 20, 10 P.M.; closed January 21, 12: 30 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{6400}$	20.5mm	turgor gone, dead
. . . .	24.5 "	" " "
$\frac{1}{12800}$	28.5 "	turgid, living
. . . . .	24.0 "	" "

53. AMIDO-PROPIONIC ACID.

(Begun January 24, 8 P.M.; closed January 25, 3 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{400}$	30.0mm	alive
$\frac{1}{800}$	36.0 "	"
$\frac{1}{1600}$	33.0 "	"
. . . .	25.0 "	"

Eight dibasic acids of the fatty series were investigated. The results are given in tables 54 to 62. In the case of oxalic acid it will be noted that the concentration in which the seedlings survive is $\frac{1}{6400}$ gram equivalent per liter, the same, then, as in case of the strong mineral acids. Oxalic acid at this concentration is practically completely dissociated. Its toxic effect in this weak solution is due only to the hydrogen ions that the solution contains, for a gram-molecule of acid potassium oxalate has the same poisonous effect as half a gram-molecule of the acid (compare table 55).

54. OXALIC ACID.

(Begun January 14, 10 P.M.)

Concentration gm. equiv. per liter	Length Jan. 15, 10 A.M.	Length Jan. 15, 6 P.M.	Remarks
$\frac{1}{3200}$	19.0mm	19.0mm	dead
$\frac{1}{6400}$	24.0 "	27.0 "	alive
$\frac{1}{12800}$	25.5 "	30.0 "	"

55. ACID POTASSIUM OXALATE.

(Begun January 16, 5 P.M.; closed January 16, 6 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{1600}$	17.0mm	flabby, dead
. . .	18.0 "	" "
$\frac{1}{3200}$	21.0 "	apparently alive (?)
. . .	21.0 "	dead
$\frac{1}{6400}$	33.5 "	apparently normal
. . .	26.5 "	" "

56. Malonic acid.

(Begun January 15, 6:30 P.M.; closed January 16, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{1600}$	18.0mm	flabby, dead
$\frac{1}{3200}$	32.0 "	apparently normal
$\frac{1}{6400}$	29.0 "	" "

57. Succinnic acid.

(Begun January 15, 4 P.M.; closed January 16, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{800}$	17.5mm	flabby, dead
. . .	16.0 "	" "
$\frac{1}{1600}$	25.0 "	alive
. . .	16.5 "	flabby, dead
$\frac{1}{3200}$	27.0 "	alive
. . .	33.5 "	"

58. Fumaric acid.

(Begun January 15, 5 P.M.; closed January 16, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	20.5mm	dead
$\frac{1}{6400}$	19.5 "	apparently living
. . .	28.0 "	apparently normal

59. Maleic acid.

(Begun January 15, 6 P.M.; closed January 16, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{1600}$	18.0mm	dead
. . .	20.5 "	"
$\frac{1}{3200}$	29.0 "	living
. . .	23.5 "	"
$\frac{1}{6400}$	29.0 "	apparently normal
. . .	line gone	" "

Malonic acid (table 56) is dissociated to the extent of 82.3 per cent. when one gram equivalent is dissolved in 1024 liters, so that at the concentration one gram equivalent in 3200 (the concentration in which the lupines live) the acid is highly dissociated though probably not completely.

Succinnic acid is a much weaker acid. It is dissociated only 30.82 per cent. when one gram equivalent is contained in 1024 liters (Ostwald). Table 56 shows that some of the seedlings survive when one gram equivalent of the acid is contained in 1600 liters.

Fumaric acid (table 58) allows the beans to survive when one gram equivalent is contained in 6400 liters, whereas maleic acid (table 59) permits them to live when one gram equivalent is present in 3200 liters. As maleic acid at the dilution 1024 is dissociated[24] 98.2 per cent. and fumaric only 78.5 per cent., we should expect the latter to be less poisonous than the former, if the toxic action be due to the hydrogen ions alone. That the opposite apparently takes place seems to show that the anions of fumaric acid exert a toxic action at this high state of dilution. Whether this is true or not can only be definitely settled by investigating the action of a salt of the acid the cathion of which has no toxic effect. We do not place much reliance on the results obtained from these two acids as it is questionable whether the substances were perfectly pure.

60. MALIC ACID.

(Begun January 28, 6 P.M.; closed January 29, 9 A.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{1600}$	18.5mm	flabby, dead
....	17.5 "	" "
$\frac{1}{3200}$	27.5 "	alive
....	20.5 "	"
$\frac{1}{6400}$	25.0 "	"

In a solution of malic acid (table 60) the seedlings survive when one gram equivalent is present in 3200 liters. This is about

[24] See Ostwald, Zeitschr. f. physik. Chem., 3: 380.

what one would expect considering the degree of the dissociation of this acid and the fact that at this concentration the hydrogen ions alone are active.

61. Aspartic acid.

(Begun January 24, 9 P.M.; closed January 25, 4 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	18.5mm	dead
....	16.5 "	"
$\frac{1}{6400}$	28.0 "	alive
....	31.0 "	"
$\frac{1}{12800}$	20.0 "	"
....	26.0 "	"

Aspartic acid (table 61) has a strong toxic action, the seedlings only surviving when the solution contains $\frac{1}{6400}$ gram-molecule per liter. The electrical conductivity of this acid is not given in Ostwald's tables. It is not probable that the acid is completely dissociated at this concentration, however. Whether the anion is active toxically can be determined by investigating the action of the sodium salt of the acid.

62. Tartaric acid.

(Begun January 15, 5 P.M.; closed January 16, 3 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{3200}$	19.0mm	dead
....	20.0 "	"
$\frac{1}{6400}$	29.0 "	alive
....	21.0 "	"

Tartaric acid (table 62) gives the limit $\frac{1}{6400}$ gram equivalent per liter. This acid is a relatively strong acid and is practically completely dissociated at this high dilution. We get only the effect of the hydrogen ions here, for a solution of sodium tartrate of like strength would not kill the seedlings.

Citric acid (table 63) was investigated in this connection. The critical limit, $\frac{1}{3200}$ gram equivalent per liter, found for this

acid is what one would have expected it to be from the concentration of the hydrogen ions in this solution.

63. CITRIC ACID.

(Begun January 24, 9 P.M.; closed January 25, 4 P.M.)

Concentration gm. equiv. per liter	Length	Remarks
$\frac{1}{1600}$	17.0mm	dead
....	17.0 "	"
$\frac{1}{3200}$	20.0 "	living
....	20.0 "	"
$\frac{1}{6400}$	27.5 "	"
....	26.0 "	"
$\frac{1}{12800}$	28.5 "	"
....	26.0 "	"

The poisonous action of eleven acids of the aromatic series has been determined. The acids of this series are of special interest, for the undissociated molecules as well as the anions in nearly all cases possess a distinct toxic action of their own, even at great dilutions.

64. BENZOIC ACID.

(Begun January 14, 8 P.M.)

Concentration gm. mol. per liter	Length January 15, 9 A.M.	Length January 15, 6 P.M.	Remarks
$\frac{1}{3200}$	20.0mm		dead
....	18.0 "		"
$\frac{1}{6400}$	22.5 "	24.0mm	living
....	24.0 "	27.0 "	"
$\frac{1}{12800}$	26.5 "	29.0 "	"
....	23.0 "	25.0 "	"

65. HIPPURIC ACID.

(Begun January 23, 9 P.M.; closed January 24, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	20.5mm	dead
....	20.0 "	"
$\frac{1}{6400}$	26.5 "	alive
....	24.5 "	"
$\frac{1}{12800}$	28.5 "	"

Benzoic and hippuric acids (tables 64 and 65) are both relatively weakly dissociated, the former 21.61 per cent. and the latter 37.51 per cent. at the dilution 1024, according to Ostwald. Both of these acids kill the lupines until the concentration $\frac{1}{6400}$ gm. mol. per liter is reached. It is not probable that these weak acids are completely dissociated even at this great dilution. The result shows that here the toxic effect is due in a high degree to the undissociated molecules and the anions present. Whether the undissociated acid is more poisonous than the anions can be determined by testing the action of the sodium salts.

66. CINNAMIC ACID.

(Begun January 23, 9 P.M.; closed January 24, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{800}$	15.5mm	turgor lost, dead
...	15.5 "	" " "
$\frac{1}{1600}$	16.0 "	" " "
...	16.5 "	" " "
$\frac{1}{3200}$	18.0 "	" " "
...	17.5 "	" " "
$\frac{1}{6400}$	23.5 "	" " "
...	20.5 "	" " "
$\frac{1}{12800}$	29.5 "	turgid, apparently normal
...	17.5 "	" " "

Cinnamic acid (table 65) is only dissociated to the extent of 17.34 per cent. at 1024, and yet in a solution of it the lupines will not survive until the acid is diluted so that it contains only $\frac{1}{12800}$ gm. mol. per liter. At this dilution we know that hydrogen ions are no longer harmful to the plants, hence the strong toxic action of this acid is due to the anions and the undissociated molecules present in the solution.

Another interesting group is that of the oxy-benzoic acids. The results obtained from the three monoxy-benzoic acids are given in tables 67 to 69. It will be seen that salicylic acid has the greatest poisonous action, the seedling surviving in a solution

that contains 1 gm. mol. in 6400 liters; then follows meta-oxy-benzoic acid, which is only fatal after the concentration 1 gm. mol. in 3200 liters is overstepped; and finally para-oxy-benzoic acid of which the radicles will bear 1 gm. mol. in 1600 liters.

67. SALICYLIC ACID.

(Begun January 14, 9 P.M.)

Concentration gm. mol. per liter	Length Jan. 15, 9 A.M.	Length Jan. 15, 6 P.M.	Remarks
$\frac{1}{3200}$	16.0mm		dead
....	18.5 "		"
$\frac{1}{6400}$	24.5 "	26.0mm	alive
....	18.5 "		dead
$\frac{1}{12800}$	26.0 "	29.0 "	alive

68. META-OXY-BENZOIC ACID.

(Begun January 23, 8 P.M.)

Concentration gm. mol. per liter	Length Jan. 24, 12 M.	Length Jan. 25, 3 P.M.	Remarks
$\frac{1}{1600}$	19.5mm		flabby, dead
....	18.0 "		" "
$\frac{1}{3200}$	23.5 "	28.0mm	living
....	23.5 "	28.5 "	"
$\frac{1}{6400}$	29.0 "		apparently n'r'ml
....	28.0 "		" "
$\frac{1}{12800}$	20.5 "		" "
.....	24.5 "		" "

69. PARA-OXY-BENZOIC ACID.

(Begun January 23, 8 P.M.)

Concentration gm. mol. per liter	Length Jan. 24, 12 M.	Length Jan. 24, 7 P.M.	Remarks
$\frac{1}{1600}$	19.0mm		flabby, dead
....	25.0 "	26.0mm	living
$\frac{1}{3200}$	24.5 "	26.0 "	"
....	27.5 "	29.5 "	"
$\frac{1}{6400}$	32.5 "		apparently n'r'ml
....	32.0 "		" "
$\frac{1}{12800}$	25.5 "		" "
.....	33.5 "		" "

The order of the poisonous action of these acids is, then, ortho, meta and para. This is also the order of their electrolytic dissociation, the degrees of dissociation of the three acids at the dilution 1024 being 62.80 per cent., 25.70 per cent. and 15.68 per cent. respectively, according to Ostwald. Whether the toxic action of these acids at the concentration at which they are fatal to the lupines is due in part to the anions here also calls for an investigation of the sodium salts.

As typical examples of other oxy-benzoic acids protocatechuic and gallic acids were chosen (see tables 70 and 71). The concentration of the former in which the beans survive is $\frac{1}{3200}$ gm. mol. per liter. The degree of dissociation of this acid at 1024 is 16.68 per cent., somewhat higher, then, than para-oxy-benzoic acid. Considering the action of the hydrogen ions alone, we should expect protocatechuic acid to be somewhat more poisonous than para-oxy-benzoic acid. It seems probable, however, that the action of the undissociated molecules and the anions can not be considered *nil* at the concentration 3200.

In the case of gallic acid, which is dissociated 18.72 per cent. at 1024, the seedlings survive only at the concentration 6400 as table 71 shows. Here clearly the anions and the undissociated molecules must have a toxic action of their own even at this high dilution, for the acid can clearly not be considered as completely dissociated.

70. PROTOCATECHUIC ACID.

(Begun January 24, 8 P.M.; closed January 25, 3 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{1600}$	17.0mm	flabby, dead
....	17.8 "	" "
$\frac{1}{3200}$	24.5 "	alive
....	18.5 "	dead
$\frac{1}{6400}$	27.0 "	alive
....	29.0 "	"
$\frac{1}{12800}$	29.0 "	"
.....	28.0 "	"

71. GALLIC ACID.

(Begun January 23, 10 P.M.; closed January 24, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{1600}$	18.5mm	dead
$\frac{1}{3200}$	24.0 "	"
$\frac{1}{6400}$	23.5 "	alive
$\frac{1}{12800}$	28.0 "	"

Finally the action of the three mono-nitro-benzoic acids was investigated. Tables 72 to 74 show that the ortho compound is least poisonous, seedlings surviving in the concentration 6400, whereas in both the meta and para compounds the solutions proved fatal until the concentration 12,800 was reached. The degrees of dissociation of these acids at 1024 are 87.9 per cent., 44.4 per cent. and 46.4 per cent. respectively. It is clear that in case of the meta and para acids, the toxic effect at 12,800 can no longer be due to hydrogen ions, and consequently must be ascribed to the undissociated molecules and the anions; as the concentration of the former is not great at this high dilution, it seems probable that the toxic action is mainly due to the anions. An investigation of the sodium salts will, of course, be necessary to decide this point definitely. Ortho-nitro-benzoic acid is practically completely dissociated at 6400. The anions of this acid are therefore less poisonous than hydrogen ions. The action of a solution of the sodium salt will very likely confirm this.

72. ORTHO-NITRO-BENZOIC ACID.

(Begun January 16, 5 P.M.; closed January 17, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	19.0mm	flabby, dead
....	18.5 "	" "
$\frac{1}{6400}$	36.0 "	apparently normal, living
....	29.0 "	" " "

73. META-NITRO-BENZOIC ACID.

(Begun January 16, 3 P.M.; closed January 17, 1 P.M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{6400}$	20.5mm	dead
....	16.0 "	"
$\frac{1}{12800}$	36.0 "	apparently normal
....	36.0 "	" "

74. PARA-NITRO-BENZOIC ACID.

(Begun January 16, 6 P.M.; closed January 17, 12 M.)

Concentration gm. mol. per liter	Length	Remarks
$\frac{1}{3200}$	17.0mm	flabby, dead
....	17.0 "	" "
$\frac{1}{6400}$	21.0 "	dead
....	19.0 "	"
$\frac{1}{12800}$	33.0 "	apparently normal
....	33.0 "	" "

That the modern theory of solutions would throw light on their physiological action was to be expected. From the foregoing detailed results it is evident that in the case of plants the toxic action of solutions of electrolytes, when dissociation is practically complete, is due to the action of the ions present. When dissociation is not complete, the undissociated part of the electrolytes may also exert a toxic effect, as has been pointed out in several instances. We have here then, as it were, a recognition of the theory of electrolytic dissociation by the organic world.

Mr. F. D. Heald, Fellow in Botany at the University of Wisconsin, has investigated the action on other plants of a considerable number of the solutions which we have tested. The results that he obtained are presented in an accompanying paper. They are perfectly analogous to those that we have found, and hence strongly confirm our conclusions.

It is clear that a knowledge of the mere presence of a metal or other element in a solution does not allow one to draw a conclusion as to its physiological action; it must also be known as to whether that element exists as an ion by itself or is combined with other elements to form a complex ion. If the addition of certain substances to a solution containing a physiologically active ion forms a complex ion of much less powerful action, it follows that these additional ingredients afford a means of reducing, so to speak, the physiological action of the simple ion.

Although this work has thus far been carried out only with higher plants, investigations on bacteria that are being carried on in this connection at the Bacteriological Laboratory of the University of Wisconsin have already yielded results supporting the theory. Anyone inspecting Miquel's table of the efficiency of antiseptics in Sternberg's "Manual of Bacteriology," and at the same time bearing in mind the theory of Arrhenius, although the concentrations are given in per cent. instead of chemical equivalents, will be able to see in it, only in rough outline to be sure, the corroboration of the views here advanced. Experiments on animals are contemplated.

It will be seen that a wide field for research along physiological lines opens up by applying to the field of biology the dissociation theory that has proved so fertile in chemistry and physics. Further work in this direction, using the latest and best that the new physical chemistry has to offer, it is to be hoped will place our knowledge of the physiological action of solutions of electrolytes on a better basis than the purely empirical one on which it has thus far rested. It does not seem too much to expect that the effects of such study will soon be felt in agriculture and therapeutics, while bacteriological study pursued from the standpoint of the new theory will yield important additions to our knowledge of antiseptics.

UNIVERSITY OF WISCONSIN, MADISON.

ON THE TOXIC EFFECT OF DILUTE SOLUTIONS OF ACIDS AND SALTS UPON PLANTS.

F. D. HEALD.

(WITH PLATE VII)

1. INTRODUCTION.

The desire for a deeper and clearer insight into the subject of nutrition of plants has led many botanical investigators to endeavor to determine the poisonous or nutritive qualities of a large number of compounds. Within the last decade a considerable number of papers have appeared dealing with the toxic effect of compounds which are generally classed as non-nutritive. The majority of these older experiments have been along the same line, and so far as known the compounds have been prepared by making solutions of a certain per cent. by weight. During the last year Kahlenberg and True[1] have carried out numerous experiments with very many inorganic and organic acids and various salts in which a different method was employed. In these experiments the solutions were prepared according to gram equivalents, and the results obtained are extremely interesting both from the chemical and the biological point of view. All of the experiments alluded to were carried out with a single plant, *Lupinus albus*.

It is important to know whether these results can be confirmed by the use of other plants, which might be expected to differ in their reactions; and to this end, at the suggestion of Dr. Kahlenberg, the present investigation has been made.

Before taking up the results in detail it may be well to present a few general considerations in regard to plant, or rather protoplasmic, poisons. Compounds which have a toxic effect upon animals are generally poisonous to plants, although we find different degrees of sensibility to the same compound in

[1] BOT. GAZ. **22**: 81. 1896.

both plants and animals. The toxic effect of a substance is evidently due to one of two things. In plant tissue the effect upon the *turgescence* of the cell must play an important part,[2] since when the turgor-pressure is suddenly and decidedly decreased, the growth is either retarded or inhibited. An inhibition or a retardation of growth must then be regarded as a symptom of poisoning. In comparison with turgescence the *direct effect* upon the protoplasm is by far the more important, since in simple turgor experiments the retardation of growth is due to the irritation of the protoplasm as well as to the turgor-change. Now, since the irritability of the protoplasm of different plants differs widely, we may reasonably expect quite a wide range in the amount of different compounds which various plants will withstand.

Why and how certain substances have a toxic effect, and certain others a nutritive value, is not known. For example, it is at present impossible to say why it is that potassium sulfate has a nutritive value while copper sulfate produces a toxic effect. Those substances which are poisonous to plants are generally such substances as are not accessible to plants in their normal habitats, at least to any extent, while those substances which are generally present in the soil have no injurious effect, or at least not in the same degree of concentration at which we find them in the soil. If the poisonous action of various substances is a mere matter of adaptation and adjustment, as seems to me highly probable, then we might expect that by adding gradually more and more copper sulfate to the soil in which a plant is growing it would come in the course of time to adapt itself to quite a large amount of this salt, which is normally extremely poisonous to the majority of plants. So far as known no experiments of exactly this nature have been carried out, and an experimental test of this would be highly interesting.

2. Method.

In the experiments performed, three different plants were used: *Pisum sativum*, *Zea Mais*, and *Cucurbita Pepo*. I describe

[2] Annals of Botany 9: 385. 1895.

first the method of germination. The peas were placed in a beaker, covered with distilled water and allowed to soak for twenty-four hours; they were then placed in a Petri-dish between moistened sheets of filter paper and allowed to remain until the radicles just burst through the seed coats. In all the experiments it was important that the seedlings should have straight roots, since it was necessary to measure the roots at intervals to determine the growth. If the peas were allowed to remain between sheets of moistened filter paper the roots grew crooked and twisted and could not be used, so it became necessary to resort to other methods of growing them.

Two different methods were used, both of which were quite satisfactory.

1. A thin sheet of cork was perforated by means of a cork-borer with a series of holes as shown in the diagram (*fig. 1*), the large opening being just small enough to keep the pea from slipping through. This cork was then floated in a deep Petri-dish of distilled water, and as soon as the radicle had burst through the seed coats the peas were transferred to the cork. The peas were so placed that the radicle was directed toward the small opening of the cork, and the whole was covered with a sheet of filter paper which hung down into the water and thus kept the peas moist (*fig. 2*). The peas were then allowed to grow until they were of sufficient size for use in the experiments. In cases where germination was slow it was found necessary to change the distilled water several times before the seedlings were of sufficient size for use. In the majority of seedlings the roots grew quite straight.

2. Another method, quite similar to the above, was also used. Two sheets of cork were taken; one was provided with openings somewhat larger than the pea; the other sheet of cork was provided with smaller openings which would register as shown in diagram when the two corks were placed one above the other (*fig. 3*). The two sheets of cork were then wired together and the small openings were provided with glass tubes about 5^{cm} long. The whole was placed in a deep dish and the peas were

placed in the openings in such a manner that the roots grew down the glass tubes (*fig. 4*). By this method it was impossible for the roots to grow crooked.

The seedlings of *Zea Mais* and *Cucurbita Pepo* were grown in a different way since germination took place more readily, and there was not so great a tendency to grow crooked roots. The seeds were soaked in distilled water for twenty-four hours, and then placed carefully between sheets of moistened filter paper. Care was taken to place the seeds in a flat position and in most cases the roots were straight, so that the extra work of a transfer was avoided. In all cases the seedlings were allowed to grow until the roots had attained a length of about twenty millimeters. For the acids, *normal* stock solutions[3] were used, that is, solutions of the mono-basic acids like HCl would contain one gram-molecule of HCl per liter, while the di-basic acid like H_2SO_4 would contain one-half gram-molecule of H_2SO_4 per liter, so that in each case the normal solution would contain one gram of H per liter. For the stock solutions of the various salts, either solutions containing a gram-molecule per liter were used or solutions containing a certain fraction of a gram-molecule. For the seedlings of *Pisum sativum* the experiments were carried out in the following manner: The solutions in which the seedlings were to be grown were placed in small beakers of about 300^{cc} capacity. A cork of sufficient size to close the opening of the beaker was provided with a glass rod which extended down into the solution. On the end of the glass rod was a smaller cork, and the seedlings were supported on this cork by means of glass pins. The cork was then set at such a level that the cotyledons of the seedlings were just above the surface of the solution. This will also be made plain by the appended diagram (*fig. 5*).

For the seedlings of *Zea Mais* and *Cucurbita Pepo* a more convenient method was found. A small piece of sheet cork of sufficient size to float in the beaker was provided with two openings and the seedlings were placed in these so that the roots

[3] Special thanks are due to Dr. Kahlenberg for the majority of the stock-solutions, and also to Mr. Schlundt for several salt-solutions.

were immersed in the solution, and the beaker covered by a cork to prevent evaporation (*fig. 6*).

In all of the experiments performed two seedlings were used. Before placing them in the solutions they were allowed to grow until the roots had reached a length of about 20^{mm}, and then a distance of 15^{mm} was marked off from the tip of each root by means of a fine brush and India ink. The time was then recorded, and at twenty-four hours from that time, the seedlings were removed from the solutions and measured again and the growth recorded. The roots were also carefully examined for any other symptoms of poisoning besides the retardation or inhibition of growth. They were then replaced in the solutions and allowed to stand for another twenty-four hours when measurements were again made. In all cases the seedlings were grown in a dark chamber with nearly a uniform temperature (21°–23° C.) The lengths given in the tables are the average growth per twenty-four hours.

The mixture of the solutions for the growth of seedlings was made as follows:

10^{cc} of nor. sol. to $1000^{cc} = \frac{N}{100}$
25^{cc} of $\frac{N}{100}$ to $200^{cc} = \frac{N}{800}$
100^{cc} of $\frac{N}{800}$ to $200^{cc} = \frac{N}{1600}$
100^{cc} of $\frac{N}{1600}$ to $200^{cc} = \frac{N}{3200}$ etc.

3. H-ACIDS.

Two seedlings of *Pisum sativum* were placed in each of the solutions of the strengths shown in the table and the growth recorded for forty-eight hours.

Acids.		$\frac{N}{1600}$	$\frac{N}{3200}$	$\frac{N}{6400}$	$\frac{N}{12800}$
HCl	1st 24 hours...	.....	.....	3.25^{mm}	4.75^{mm}
	2d 24 hours...	.....	.....	.....	7.5 "
H_2SO_4	1st 24 hours...	.....	.....	3.5 "	12.5 "
	2d 24 hours...	.....	.....	.....	5.25 "
HNO_3	1st 24 hours...	.....	.....	.....	6.5 "
	2d 24 hours...	.....	.....	.....	7. "
HBr	1st 24 hours...	.....	.....	.....	5.5 "
	2d 24 hours...	.....	.....	.....	6.25 "

In the $\frac{N}{1600}$ and $\frac{N}{3200}$ solutions no growth whatever occurred, and at the end of the first twenty-four hours the tips of the roots were very soft and flabby and were considered as dead. In the $\frac{N}{6400}$ solution a growth occurred in the HCl and H_2SO_4 solutions for the first twenty-four hours, but the second twenty-four hours showed no additional growth, while the roots were very soft and flabby. In the HNO_3 and HBr no growth whatever took place in the $\frac{N}{6400}$ solution. In the $\frac{N}{12800}$ solution the seedlings grew for the entire forty-eight hours and at the end of that time the roots were very rigid and did not show any symptoms of poisoning.

It is worthy of note here that in case of the seedlings in the $\frac{N}{6400}$ solution a large number of lateral roots were formed before the root was killed. The delicate cells of the root tip were the first to be affected by the poison, and thus having its main growing point destroyed the plant was stimulated to the production of lateral roots in its struggle to withstand the effects of the poison. Another point which cannot be overlooked is the fact that in the $\frac{N}{1600}$ solution of HCl the roots of the seedlings were covered with a dense growth of fungus at the end of the experiment. The species of the fungus was not determined. So far as known from experiments it is true that fungi generally are able to withstand stronger solutions of poison than green plants. *Penicillium*, for example, will grow in a comparatively strong solution of $CuSO_4$. A solution of $\frac{N}{100}$ acetic acid, after standing for some time in the laboratory, was found to be filled with a dense growth of fungus, the species of which was not determined.

Two seedlings of *Zea Mais* were placed in each of the solutions recorded in the following table, and the growth recorded at periods of twenty-four hours.

From the degree of concentration at which the seedlings of *Pisum sativum* were killed it was thought that the solutions $\frac{N}{3200}$, $\frac{N}{6400}$, and $\frac{N}{12800}$ ought to show the strength of solution which these seedlings would withstand, and so at first only solutions of that strength were used. In all of these, however, the

growth was considerable for the first twenty-four hours, with generally an increase in the amount of growth for the next twenty-four hours. A glance at the following table will also show that the growth in the $\frac{N}{3200}$ and $\frac{N}{6400}$ solutions was somewhat less than in the $\frac{N}{12800}$ solution, so that even if the growth was not inhibited in the former a very perceptible retardation of the growth occurred. Since growth was not entirely inhibited in the solutions from $\frac{N}{3200}$ upward, seedlings were placed in two stronger solutions, $\frac{N}{800}$ and $\frac{N}{1600}$. In the $\frac{N}{800}$ solution no growth whatever occurred, and at the end of the first twenty-four hours the roots were very soft and flabby near the tip. In the $\frac{N}{1600}$ solution, however, the roots showed quite an increase in length for the first twenty-four hours but for the second twenty-four hours showed no increase, so that the $\frac{N}{1600}$ solution is the strength at which the roots were killed.

ZEA MAIS.

Acids.		$\frac{N}{800}$	$\frac{N}{1600}$	$\frac{N}{3200}$	$\frac{N}{6400}$	$\frac{N}{12800}$
HCl	1st 24 hours	..	3.5 mm	8.25 mm	11.5 mm	11.25 mm
	2d 24 hours	..	.....	18.25 "	16 "	15.25 "
H_2SO_4	1st 24 hours	..	2.75 "	12.5 "	11.5 "	17.5 "
	2d 24 hours	..	.....	27.5 "	14 "	33 "
HNO_3	1st 24 hours	..	4.5 "	7 "	14 "	16.5 "
	2d 24 hours	..	.5 "	9 "	11.5 "	29 "
HBr	1st 24 hours	..	3 "	7.5 "	12 "	15 "
	2d 24 hours	..	.....	8.25 "	13.75 "	30.5 "

A glance at the table for *Pisum sativum* shows a very considerable difference in the amount of the acids which the seedlings could withstand. In the case of *Pisum sativum* the $\frac{N}{6400}$ solution was of sufficient strength to inhibit the growth, while in the case of the *Zea Mais* seedlings it required a $\frac{N}{1600}$ solution, or a solution four times as concentrated. This very great difference in the degree of irritability is the more worthy of note, since the one, *Pisum*, has its reserve food supply stored in the form of carbohydrates, while corn contains quite a large amount of fatty material.

Two seedlings of *Cucurbita Pepo* were placed in each of the solutions of the strength shown in the following table:

CUCURBITA PEPO.

Acids.	$\frac{N}{1600}$	$\frac{N}{3200}$	$\frac{N}{6400}$	$\frac{N}{12800}$
H Cl 1st 24 hours...	.....	.....	2.5 mm	3.75 mm
H Cl 2d 24 hours...	.....	.....	3.25 "	9.25 "
H_2SO_4 1st 24 hours...	.....	.....	9. "	6. "
H_2SO_4 2d 24 hours...	.....	.....	4.75 "	6.5 "
H NO_3 1st 24 hours...	.....	.....	5.25 "	3.5 "
H NO_3 2d 24 hours...	.....	.....	8. "	4. "
H Br 1st 24 hours...	.....	.....	4.5 "	5.75 "
H Br 2d 24 hours...	.....	.....	2. "	1.75 "

Seedlings were set first in the $\frac{N}{1600}$ and $\frac{N}{3200}$ solutions and after the first twenty-four hours no growth had taken place and the root tips were soft and flabby; they were, however, replaced in the solutions and allowed to stand for another twenty-four hours. At the end of the forty-eight hours no additional growth had occurred. In the $\frac{N}{6400}$ and $\frac{N}{12800}$ solutions the growth was considerable for both the first and second twenty-four hours. Then the strength of solution necessary to inhibit the growth is $= \frac{N}{3200}$, which is less than in the case of *Pisum sativum* seedlings, but more than in the case of *Zea Mais* seedlings.

The relative sensibility to the acid poisons then is as follows:

1. Pisum sativum, seedlings killed by $\frac{N}{6400}$ solution.
2. Zea Mais, seedlings killed by $\frac{N}{1600}$ solution.
3. Cucurbita Pepo, seedlings killed by $\frac{N}{3200}$ solution.

Before discussing the results of the experiments with the acids, a short statement in regard to the so-called theory of *electrolytic dissociation* will be necessary. The theory was published by Arrhenius[4] in 1887 and amounts practically to this: Aqueous solutions of acids, bases, or salts are, to a greater or less extent, broken up or dissociated into part-molecules, the so-called *ions*. It is not necessary to mention here the facts which confirm this theory, but it suffices to say that it now stands on a

[4] Zeitschrift für Physikalische Chemie 1: 631.

comparatively firm experimental basis. The amount of dissociation depends upon the strength of the solution. The more dilute the solution, the more complete is the dissociation, until at infinite dilution the dissociation is complete. When a certain acid, for example HCl, dissociates, the result is H-ions and Cl-ions; the H-ions are charged positively with electricity, while the Cl-ions are charged negatively, there being an equal number of positive and negative ions in order to preserve equilibrium. The manner of dissociation may be expressed by H^+ and Cl^-. In the case of a salt, as $CuSO_4$, for example, the dissociation will take place as $^+Cu^+$ ions and $^-SO_4^-$ ions, and in a similar manner for other salts, the radicle always being the electro-negative *ion* and the basic element or radicle the electro-positive ion.

A comparison of the results obtained with the acids, with some investigations on the plant cell, is interesting as affording some light upon the nature of the effect produced by the acids. Klemm[5] states that ½ to 1 pro mille HNO_3 causes the streaming motion of the protoplasm in the hairs of *Trianea* to cease and also produces a granulation and aggregation of the protoplasm. A 1 promille solution of HNO_3 would contain 1 gram of HNO_3 to 1000^{cc} of water. The strength of solution which killed the roots of *Pisum sativum* was $\frac{N}{6400}$, which is equivalent to 1 gram of HNO_3 to 101,587^{cc} of water. For *Zea Mais* roots the killing point was the $\frac{N}{1600}$ solution, which is equivalent to 1 gram of HNO_3 to 25,396^{cc} of water. For the *Cucurbita Pepo* seedlings the roots were killed by the $\frac{N}{3200}$ solution, which is equivalent to 1 gram of HNO_3 to 50,793^{cc} of water. From these figures it will be seen that the strength which was required to produce a disorganization of the protoplasm in the *Trianea* hairs was so much greater than that required to kill the roots of the seedlings, that the toxic effect can hardly be due to a visible disorganization of the protoplasm. Klemm also states that the same thing takes place with equally dilute solutions of H_2SO_4 and HCl.

[5] Desorganisationserscheinungen der Zelle; Jahrbücher f. wiss. Botanik **28**: 658–964. 1895.

In regard to the relation of these results to the theory of dissociation, Kahlenberg and True[6] have demonstrated quite clearly in their work that it is the H^+ ion which produces the toxic effect. HCl will form H^+ ions and Cl^- ions; H_2SO_4 will dissociate first into H^+ and HSO_4^-, but the final product will be two H^+ ions and $^-SO_4^-$ ions; HNO_3 splits to form H^+ ions and NO_3^- ions; HBr will dissociate to form H^+ ions and Br^+ ions. As has been before stated, the more dilute the solution, the more complete the dissociation, but with the dilutions used for the acids, dissociation would be practically complete, so that we need not take into consideration anything but the H^+ ions and the electro-negative ions. Take for example NaCl, which will dissociate as Na^+ and Cl^- ions. Now NaCl at the dilution at which the HCl was effective is practically without effect; the Cl^- ions must then be considered as non-poisonous in the HCl, since both HCl and NaCl contain Cl^- ions. Now if the Cl^- ions are without any toxic effect at this dilution it is plain that the poisonous effect must be due to the H^+ ions.

The H_2SO_4 may be considered in the same way. If a plant be subjected to an equally concentrated solution of K_2SO_4, which is one of the compounds from which plants quite commonly obtain their potassium, it would be entirely unharmed at that dilution. The K_2SO_4 would dissociate to form K^+ ions and SO_4^- ions, and since K_2SO_4 and H_2SO_4 solutions have SO_4^- ions in common it is evident that the SO_4^- ions of the H_2SO_4 are non-poisonous. This then leaves only the H^+ ions to produce the toxic effect. The non-poisonous character of the SO_4^- ions can be shown by the action of other sulfates, such as $CaSO_4$, $MgSO_4$ and Na_2SO_4. Again: sulfur is a constant constituent of proteid substances, and is absorbed by all plants in the form of sulfates, so that plants are constantly subjected to the action of SO_4^- ions. The solutions were so mixed that the H_2SO_4 solutions contained the same amount of ionic H as the other acids, that is, a normal solution of H_2SO_4 contained only ½

[6] BOT. GAZ. 22:81. 1896.

gram molecule to the liter. Now the H_2SO_4 solution which contains the same amount of ionic H as the other acids kills at the same point of dilution, so that this again points to the toxic effect of the H^+ ions.

The action of HNO_3 may be discussed in a similar manner. $Ca(NO_3)_2$ is one of the common compounds by which a plant receives calcium and nitrogen and at a dilution relatively the same as that at which the acid killed the seedlings, it is without any harmful effect. It is presented to the plant in the form of $^+Ca^+$ ions and NO_3^- ions. The HNO_3 and $Ca(NO_3)_2$ contain NO_3 in common and since the NO^-_3 ions are non-poisonous it leaves the H^+ ions again as the agent which produces the toxic effect. A large part of the nitrogen contained in a plant is supplied to it in the form of nitrates, so that here again the plant is constantly subjected to the action of NO^-_3 ions. The non-poisonous character of the NO^-_3 ions may be shown by other nitrates as well.

It may seem doubtful at first whether HBr can be considered in the same way as the other acids, but Dirck[7] has found that KBr in dilute solution produces no harmful effect. Now since this would dissociate as K^+ ions and Br^- ions, it follows that in dilute solution Br-ions are non-poisonous, and hence play no part in the toxic effect of the HBr, at least not at the dilution at which the HBr killed the roots of seedlings. It will also be seen from the tables that the HBr kills the seedlings at the same degree of concentration as the other acids; now since it has been shown that the toxic effect of HCl, H_2SO_4 and HNO_3 is due to the H^- ions, we should expect HBr to kill at a different degree of concentration if the Br was poisonous also, for then we should have the sum of the effect of H^+ ions and Br^- ions. Here again the entire toxic action is produced by the H^+ ions.

It has been clearly shown by the above experiments that in the case of poisoning by acids, the harmful effect is produced entirely by the H^+ ions. By putting the results of the experiments in a different form we can get a better idea of the

[7] Bericht d. Verhdlg. d. sächs. Ges. d. Wiss. zu Leipzig **21**: 20. 1869.

extremely small amount of ionic H necessary to kill the roots of seedlings. In the case of the *Pisum sativum* seedlings one part of ionic H^- to 6,400,000 of water was sufficient to kill the roots. The roots of *Cucurbita Pepo* were killed by 1 part of ionic H^- to 3,200,000 parts of water, while the roots of *Zea Mais* were the most resistant, requiring one part of ionic H to 1,600,000 parts of water.

When expressed in the form of per cent. the extremely small amount of acid necessary to kill the *Pisum sativum* seedlings is even more apparent, and may be expressed as follows: HCl, 0.00056%; H_2SO_4, 0.00076%; HNO_3, 0.00098%; HBr, 0.00126%.

From this it will be seen that the per cent. according to weight gives a different result, showing apparently a difference in the toxic power of the acids, which would be obtained if the theory of dissociation was overlooked.

Before leaving the subject of acids and their toxic effect a few points in connection with the relation of the plant to CO_2 are worthy of note. All CO_2 which reaches the plant, whether it be the root or the green aerial parts must be brought into solution before it can be absorbed. As soon as CO_2 and water come together we no longer have simple CO_2 and water but H_2CO_3, carbonic acid. Now this carbonic acid in aqueous solution will dissociate to form two H^+ ions and $^-CO_2^-$ ions. CO_2 has been found to be poisonous to the green parts of plants, and the question which naturally suggests itself is, does the toxic effect depend simply upon the CO_2, as has always been stated, or does the ionic H of the carbonic acid bring about the poisoning? In the case of the green parts of a plant the amount of CO_2 necessary to produce a toxic effect is quite large, and this may be urged as an objection to the ionic explanation. This can however be easily explained. The CO_2 absorbed by a leaf is taken up with some difficulty, the resistance depending upon the structural porosity of the leaf and upon the permeability of the cell walls, so that it takes a very considerable external pressure or a large per cent. of CO_2 in the surrounding air to cause the

accumulation of CO_2 to any amount in the tissue of the plant since it is constantly being removed from the scenes of activity in the photosyntactic processes.

That the ionic explanation is the true one is also strengthened by the experiments of Gigliole,[8] who found that various seeds when subjected to the action of CO_2 in their dry condition, retained their vitality as well as in ordinary air, but when the seeds were soaked in water they were killed. This effect seems to me to be due to the H-ions present.

The experiments in regard to the poisonous action of CO_2 are somewhat conflicting since Jentys[9] concluded from a series of experiments that beans, lupines, rye, and wheat were not harmed by CO_2. These experiments, however, are not conclusive, since the plants were grown in earth in glass pots. The CO_2 was introduced by a tube in the floor of the pot, and since the air which was passed in contained only about $\frac{4}{12}$ per cent. CO_2 the roots were probably subjected to only a small per cent. of CO_2 in the form of carbonic acid. In the experiments which I have performed with the acids the whole plant was not killed but simply the main root, so that if the plants had been growing in the soil they would not have been killed. Fungi are also able to withstand more CO_2 than green plants, which has been shown to be the case with other acids. More experiments are necessary to prove conclusively the fact that CO_2 poisoning is due to the effect of the ionic H^-, and as soon as possible experiments with that view will be carried out.

ACETIC ACID.

CH_3COOH		$\frac{N}{400}$	$\frac{N}{800}$	$\frac{N}{1600}$	$\frac{N}{3200}$	$\frac{N}{6400}$
P. sativum	1st 24 hrs	....	.....	.....	4.75mm	1.25mm
	2d 24 hrs	....	.....	.....	5.25 "	14.5 "
Zea Mais	1st 24 hrs	....	10.25mm	15.5mm	11 "	.....
	2d 24 hrs	....	6.75 "	10.5 "	27 "	.....

[8] Gazetta chimica italiana 9: 477–478. 1879.

[9] Extrait du Bulletin de l'Académie des Sciences de Cracovie, July 1892.

Some experiments with acetic acid also were performed. In these, only seedlings of *Pisum sativum* and *Zea Mais* were used, and the results at the different dilutions are shown in the preceding table.

From the above table it will be seen that $\frac{N}{1600}$, $\frac{N}{3200}$ and $\frac{N}{6400}$ solutions were used for the seedlings of *P. sativum*. In the $\frac{N}{1600}$ solution no growth whatever occurred and at the end of the first twenty-four hours the root tips were very soft and flabby. In the two remaining solutions considerable growth resulted, but it will be seen from the amount of growth that the $\frac{N}{3200}$ solution produced a marked retardation.

For the *Zea Mais* seedlings much greater concentrations were used to start with, since it had been found in the experiments with other acids that these seedlings were much more resistant. In the $\frac{N}{400}$ solution no growth whatever occurred while in the other dilutions the growth was considerable. The figures here also show that growth was to some extent retarded in the dilutions which were not sufficient to kill the roots.

The dissociation of acetic acid is into H^+ ions and $C_2H_3O_2^-$ ions, so that here again we have to deal with H^+ ions. In this acid, however, the degree of dissociation is not complete at the dilutions which were used in the experiments. The amount of dissociation in a $\frac{N}{1024}$ solution is only 12.66 per cent. according to Ostwald,[10] and in a $\frac{N}{512}$ solution 9.14 per cent. Then here we have to deal with a certain amount of dissociated acetic acid and a certain amount which remains unchanged, the effect of which cannot be overlooked. Sodium acetate in equally strong solution is non-poisonous and since both sodium acetate and acetic acid contain $C_2H_3O_2^-$ ions in common it follows that the $C_2H_3O_2^-$ ion is non-poisonous, so that the H^+ ions and the undissociated acid are left to produce the toxic effect. The part which is played by these two will depend upon the degree of concentration of the solution.

It will be noted that in the case of both seedlings the per cent. necessary to kill the roots is much greater than in the

[10] Zeitschrift für Physikalische Chemie 3: 174.

experiments upon other acids. This fact is to be explained by the partial dissociation of the acetic acid.

It is also interesting to note that after the killing point has been found for the *Pisum sativum* roots it can be worked out by proportion for the *Zea Mais*. $\frac{N}{6400}$, the killing point in other acids for *Pisum*, is to $\frac{N}{1600}$, the killing point for *Zea Mais* with other acids, as $\frac{N}{1600}$, the killing point of acetic acid for *Pisum sativum*, is to $\frac{N}{x}$, the killing point for *Zea Mais*, that is,

$$6400 : 1600 :: 1600 : x;$$

whence $x = 400$, and a glance at the table will show that the $\frac{N}{400}$ solution was sufficient to kill the roots of *Zea Mais* seedlings.

Klemm [11] has shown that more concentrated solutions of the organic acids are necessary to produce disorganization than of the inorganic acids. This fact then falls in line with the result here obtained for the acetic acid.

4. Copper Salts.

For the copper salts stock solutions which contained $\frac{1}{160}$ gram-molecule to the liter were used. Three different copper-salts were used, copper sulfate, copper chloride, and copper acetate, and the dilutions were made as follows:

10^{cc} of $\frac{1}{160}$ to 200^{cc} = $\frac{1}{3200}$ mol.
100^{cc} of $\frac{1}{3200}$ to 200^{cc} = $\frac{1}{6400}$ mol.
100^{cc} of $\frac{1}{6400}$ to 200^{cc} = $\frac{1}{12800}$ mol. *etc.*

PISUM SATIVUM.

Copper salts.		$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.
$CuSO_4$	1st 24 hours	....	....	0.75 mm	2.5 mm	14 mm
	2d 24 hours	....	....	.....	... .	13.75 "
$CuCl_2$	1st 24 hours	....	....	0.75 "	3.25 "	15 "
	2d 24 hours	....	....	.....	3 "	8.25 "
$Cu(C_2H_3O_2)_2$	1, 24 h	....	....	0.75 "	3.5 "	12.75 "
	2, 24 h	....	....	.....	3.5 "	9 "

Experiments were carried out first with the seedlings of *Pisum sativum*, two seedlings being placed in each of the solu-

[11] Jahrbücher f. wiss. Botanik **28**: 658–664.

tions indicated in the preceding table. The amount of growth for periods of twenty-four hours was noted.

In the solutions which contained $\frac{1}{6400}$ and $\frac{1}{12800}$ molecule per liter no growth whatever was observed, and at the end of the experiment the root tips were generally quite soft and flexible and in most cases showed a faint greenish coloration. In the next dilution, $\frac{1}{25600}$ molecule, a very slight growth was observed for the first twenty-four hours but for the second twenty-four hours no growth whatever, and at the end of the experiment these roots were also soft and flexible and colored greenish. In the two next dilutions $\frac{1}{51200}$ molecule and $\frac{1}{102400}$ molecule, the growth was considerable, but it was much greater in the later solution showing that the growth was retarded to a considerable extent by the $\frac{1}{51200}$ molecule solution. In the $\frac{1}{51200}$ molecule, $CuSO_4$ solution no growth resulted for the second twenty-four hours, but this is not strange since in the others the growth was retarded to a considerable extent. Then the $\frac{1}{51200}$ molecule solution may be considered as the strength of the copper salts which will barely permit the roots to live.

A series of experiments similar to the above were also performed with seedlings of *Zea Mais* with the following results:

ZEA MAIS.

Copper salts.	$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.
$CuSO_4$ 1st 24 hours	....	....	1 mm	2.5 mm	16.5 mm
$CuSO_4$ 2d 24 hours	....	....	.....	.....	7 "
$CuCl_2$ 1st 24 hours	....	....	1 "	1.25 "	11.5 "
$CuCl_2$ 2d 25 hours	....	....	.....	.....	7.5 "
$Cu(C_2H_3O_2)_2$ 1, 24 h	....	....	.....	2 "	14 "
$Cu(C_2H_3O_2)_2$ 2, 24 h	....	....	.....	.....	13.5 "

Now since the experiments with the acids showed that the seedlings of *Zea Mais* were able to withstand a greater amount it was thought that they would likewise withstand a greater amount of copper. For this reason only the first three dilutions shown

in the above table were used, but it was found that in all except the last no growth resulted, and in the $\frac{1}{256000}$ molecule solution only a very small increase in length was noted in the $CuSO_4$ and $CuCl_2$ and none in the $Cu(C_2H_3O_2)_2$. The roots at the end of the experiment were soft and flexible and showed a greenish color similar to the roots of *Pisum sativum* in the copper solutions. Two higher dilutions were then used; $\frac{1}{512000}$ gram-molecule, and $\frac{1}{1024000}$ gram-molecule. In the first of these very slight growth occurred during the first twenty-four hours but no further growth afterwards, while in the $\frac{1}{1024000}$ solution the growth was considerable during the entire period of the experiment. The $\frac{1}{1024000}$ gram-molecule solution is to be considered as the one which will first allow the seedlings to grow. That the seedlings of *Zea Mais* should be less sensitive to acids and more sensitive to copper salts seems a little strange, but the experiments plainly show that this fact is true.

When $CuSO_4$ exists in dilute solution, it will dissociate to form $^{+}Cu^{+}$ ions and $^{-}SO_4^{-}$ ions, and at the degree of concentration of the solutions used the dissociation would be practically complete. Hence only copper-ions and $^{-}SO_4^{-}$ ions need be taken into consideration. Now it has already been shown in the case of H_2SO_4 that the SO_4^{-} ion is non-poisonous, at least in dilute solutions, so the Cu-ion is left to bring about the toxic action. $CuCl_2$, the second salt used, will dissociate to form $^{+}Cu^{+}$ ions and two Cl^{-} ions, and here also the dissociation will be practically complete in the solutions used, so that in this case we have to deal simply with $^{+}Cu^{+}$ ions and Cl^{-} ions. In the experiments with HCl it has been shown that the Cl ions are without effect, so that here also the toxic action must be due to the Cu ions. The next salt, $Cu(C_2H_3O_2)_2$ will dissociate to form $^{+}Cu^{+}$ ions and two $C_2H_3O_2^{-}$ ions, and here also the dissociation will be practically complete in the solutions used. Here then we have to deal simply with $^{+}Cu^{+}$ ions and $C_2H_3O_2$ ions. That the toxic action of this salt is due entirely to the Cu-ions can be clearly shown from the results obtained for the other copper salts. In the $CuSO_4$ and in the $CuCl_2$ the

tions indicated in the preceding table. The amount of growth for periods of twenty-four hours was noted.

In the solutions which contained $\frac{1}{6400}$ and $\frac{1}{12800}$ molecule per liter no growth whatever was observed, and at the end of the experiment the root tips were generally quite soft and flexible and in most cases showed a faint greenish coloration. In the next dilution, $\frac{1}{25600}$ molecule, a very slight growth was observed for the first twenty-four hours but for the second twenty-four hours no growth whatever, and at the end of the experiment these roots were also soft and flexible and colored greenish. In the two next dilutions $\frac{1}{51200}$ molecule and $\frac{1}{102400}$ molecule, the growth was considerable, but it was much greater in the later solution showing that the growth was retarded to a considerable extent by the $\frac{1}{51200}$ molecule solution. In the $\frac{1}{51200}$ molecule, $CuSO_4$ solution no growth resulted for the second twenty-four hours, but this is not strange since in the others the growth was retarded to a considerable extent. Then the $\frac{1}{51200}$ molecule solution may be considered as the strength of the copper salts which will barely permit the roots to live.

A series of experiments similar to the above were also performed with seedlings of *Zea Mais* with the following results:

ZEA MAIS.

Copper salts.	$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.
$CuSO_4$ 1st 24 hours	....	....	1 mm	2.5 mm	16.5 mm
$CuSO_4$ 2d 24 hours	....	....	.....	.....	7 "
$CuCl_2$ 1st 24 hours	....	....	1 "	1.25 "	11.5 "
$CuCl_2$ 2d 25 hours	....	....	.....	.....	7.5 "
$Cu(C_2H_3O_2)_2$ 1, 24 h	....	....	.....	2 "	14 "
$Cu(C_2H_3O_2)_2$ 2, 24 h	....	....	.....	.....	13.5 "

Now since the experiments with the acids showed that the seedlings of *Zea Mais* were able to withstand a greater amount it was thought that they would likewise withstand a greater amount of copper. For this reason only the first three dilutions shown

in the above table were used, but it was found that in all except the last no growth resulted, and in the $\frac{1}{256\,00}$ molecule solution only a very small increase in length was noted in the $CuSO_4$ and $CuCl_2$ and none in the $Cu(C_2H_3O_2)_2$. The roots at the end of the experiment were soft and flexible and showed a greenish color similar to the roots of *Pisum sativum* in the copper solutions. Two higher dilutions were then used; $\frac{1}{81200}$ gram-molecule, and $\frac{1}{102400}$ gram-molecule. In the first of these very slight growth occurred during the first twenty-four hours but no further growth afterwards, while in the $\frac{1}{102400}$ solution the growth was considerable during the entire period of the experiment. The $\frac{1}{102400}$ gram-molecule solution is to be considered as the one which will first allow the seedlings to grow. That the seedlings of *Zea Mais* should be less sensitive to acids and more sensitive to copper salts seems a little strange, but the experiments plainly show that this fact is true.

When $CuSO_4$ exists in dilute solution, it will dissociate to form $^{+}Cu^{+}$ ions and $^{-}SO_4^{-}$ ions, and at the degree of concentration of the solutions used the dissociation would be practically complete. Hence only copper-ions and $^{-}SO_4^{-}$ ions need be taken into consideration. Now it has already been shown in the case of H_2SO_4 that the SO_4^{-} ion is non-poisonous, at least in dilute solutions, so the Cu-ion is left to bring about the toxic action. $CuCl_2$, the second salt used, will dissociate to form $^{+}Cu^{+}$ ions and two Cl^{-} ions, and here also the dissociation will be practically complete in the solutions used, so that in this case we have to deal simply with $^{+}Cu^{+}$ ions and Cl^{-} ions. In the experiments with HCl it has been shown that the Cl ions are without effect, so that here also the toxic action must be due to the Cu ions. The next salt, $Cu(C_2H_3O_2)_2$ will dissociate to form $^{+}Cu^{+}$ ions and two $C_2H_3O_2^{-}$ ions, and here also the dissociation will be practically complete in the solutions used. Here then we have to deal simply with $^{+}Cu^{+}$ ions and $C_2H_3O_2$ ions. That the toxic action of this salt is due entirely to the Cu-ions can be clearly shown from the results obtained for the other copper salts. In the $CuSO_4$ and in the $CuCl_2$ the

toxic action was due to the Cu alone, the $^{-}SO_4^{-}$ ions and the Cl^{-} ions being without effect. Now in the case of the copper acetate if the $C_2H_3O_2^{-}$ was poisonous we should expect that the solution would kill the seedlings at a greater dilution, since it would have the combined action of H^{+} ions and $C_2H_3O_2^{-}$ ions, but the experiments show the killing point for the acetate to be the same as for the other salts. Hence we must conclude that the $C_2H_3O_2$ ion is without any poisonous effect at this dilution.

Nageli[12] has shown that copper by its mere presence in the water in which plants were growing was able to produce toxic effects, and Löw[13] has also shown that water which was distilled from a copper retort resulted injuriously to plants. True also found that it was impossible to use brass pins to fasten seedlings to a cork while growing in various solutions. That the poisonous effect was due to the Cu and Zn of the pins is shown by the fact that as soon as glass pins were substituted the plants grew without any difficulty. We commonly think of copper as being insoluble but in the cases mentioned above it is very certain that enough Cu-ions were formed in the solutions to produce the toxic action.

A better idea of the extremely small amount of copper necessary to kill the seedlings can be obtained by putting the results in a different form. The seedlings of *Pisum sativum* were killed by the $\frac{1}{2500}$ gram-molecule solution which is the same as one part of copper to 404,423 parts of water. The seedlings of *Zea Mais* were killed by the $\frac{1}{5120}$ gram-molecule solution, which is equivalent to one part of copper to 808,846 parts of water.

Before leaving the copper salts one other fact should be mentioned. At the end of the experiments some of the seedlings were transferred to distilled water to see if the roots would revive, but in no case would the main root grow. The seedling as a whole was not dead, but would continue to grow and produce secondary roots above the part of the root which had been killed,

[12] Denkschr. d. schweizerischen naturf. Ges. **33**: 1. 1893.

[13] Landw. Jahrb. **20**: 235. 1891.

so that when it has been stated that the seedling was killed only the root has been referred to.

5. Nickel and Cobalt.

A series of experiments were carried out with two nickel salts, $NiSO_4$ and $Ni(NO_3)_2$ and two cobalt salts, $CoSO_4$ and $Co(NO_3)_2$. The same two seedlings, *Pisum sativum* and *Zea Mais* were used. First as to the results obtained with the seedlings of *Pisum sativum*. Seedlings were placed in the dilutions shown in the following table and the growth recorded for periods of twenty-four hours.

PISUM SATIVUM.

Nickel and Cobalt.		$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.
$NiSO_4$	1st 24 hours	1.25 mm	1.5 mm	1.75 mm	10 mm	13 mm
	2d 24 hours	..	..	..	6.5 "	5 "
$Ni(NO_3)_2$	1st 24 hours	1 "	.75 "	2.25 "	7 "	13.25 "
	2d 24 hours	..	..	..	..	11.75 "
$CoSO_4$	1st 24 hours	1 "	4 "	7.5 "	6.25 "	..
	2d 24 hours	..	..	3.5 "	5.75 "	..
$Co(NO_3)_2$	1st 24 hours	1 "	3 "	4.25 "	7.5 "	..
	2d 24 hours	..	..	1 "	4.75 "	..

First as to the nickel salts. In the $\frac{1}{6400}$, $\frac{1}{12800}$ and $\frac{1}{25600}$ gram-molecule solutions a small amount of growth was observed for the first twenty-four hours but no further growth resulted. In the $\frac{1}{51200}$ and $\frac{1}{102400}$ gram-molecule solutions considerable growth occurred for the entire period, except in the $\frac{1}{51200}$ nickel nitrate, in which solution the normal conditions were not fulfilled, since the plants suffered from a copious growth of bacteria. At the end of the experiment the roots which were killed were not soft and flabby as in the acid or copper poisoning, but were extremely rigid. The roots were so rigid and brittle that if the seedlings were dropped on the table they would snap in pieces almost like so much glass. For the cobalt salts growth was observed in the $\frac{1}{6400}$ and $\frac{1}{12800}$ gram-molecule solutions for the first twenty-four hours, but no growth afterwards, while in the two next weaker solutions growth continued for the entire period. The roots

which were killed by the cobalt solutions were also very brittle and rigid, the same as in the nickel solutions.

The results obtained for the seedlings of Zea Mais in the different solutions are given in the following table:

ZEA MAIS.

Nickel and Cobalt.	$\frac{1}{1600}$ mol.	$\frac{1}{3200}$ mol.	$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.
$NiSO_4$ 1st 24 hours	..	..	2 mm	3 mm	2.5 mm	11 mm
$NiSO_4$ 2d 24 hours	..	..	..	..	..	8 "
$Ni(NO_3)_2$ 1st 24 h'rs	..	..	..	5.5 "	4 "	17.5"
$Ni(NO_3)_2$ 2d 24 h'rs	..	..	..	..	..	16.5"
$CoSO_4$ 1st 24 hours	2.5 mm	1 mm	20.5 "	27 "	..	..
$CoSO_4$ 2d 24 hours	..	..	15 "	18 "	..	..
$Co(NO_3)_2$ 1st 24 h'rs	2 "	3.25"	22.5 "	19 "	..	..
$Co(NO_3)_2$ 2d 24 h'rs	..	..	19 "	34 "	..	..

The seedlings were set first in $\frac{1}{6400}$, $\frac{1}{12800}$, $\frac{1}{25600}$ and the $\frac{1}{51200}$ gram-molecule solution of $NiSO_4$. The first three showed growth for the first twenty-four hours but none afterwards, while those in the last solution grew for the entire period of the experiment. For the $Ni(NO_3)_2$ only the three solutions shown in the first table were used; in the first two growth occurred during the twenty-four hours, but none afterwards, so that the killing point for the nickel salts may be considered the $\frac{1}{25600}$ gram-molecule solution.

Reasoning from the results found for the *Pisum sativum* seedlings it was thought that the killing point for the cobalt salts might be found by the $\frac{1}{6400}$ and $\frac{1}{12800}$ gram-molecule solutions, but both of these dilutions gave a considerable growth for the entire forty-eight hours. Seedlings were then set in two stronger solutions, $\frac{1}{1600}$ and $\frac{1}{3200}$ gram-molecules. In these the roots grew for the first twenty-four hours, but no further growth had resulted at the second measurement. The killing point for the cobalt salts is thus placed at the $\frac{1}{3200}$ gram-molecule solution.

One point which must be noted in connection with all of the experiments with the nickel and cobalt salts is that in nearly every case a certain amount of growth resulted during the first

twenty-four hours of the experiments in which the roots were killed. The nickel and cobalt are quite poisonous, but the toxic effect is not felt by the plant as soon as in the case of acid or copper poisoning. The toxic action of nickel is seen to be greater than cobalt, by the results on both *Pisum sativum* and *Zea Mais*.

In the case of the $NiSO_4$ the dissociation will be into $^{+}Ni^{+}$ ions and $^{-}SO_4^{-}$ ions. The $CoSO_4$ will form $^{+}Co^{+}$ ions and $^{-}SO_4^{-}$ ions. At the dilution used for both of these salts the dissociation will be practically complete. It has already been shown that the SO_4^{-} ion is non-poisonous, so the $^{+}Ni^{+}$ ions and the $^{+}Co^{+}$ ions are left to bring about the toxic action.

The $Ni(NO_3)_2$ will form in dilute solution $^{+}Ni^{+}$ ions and two NO_3^{-} ions. The $Co(NO_3)_2$ will dissociate to form $^{+}Co^{+}$ ions and two NO_3^{-} ions. Here also the dissociation will be practically complete at the dilutions used, so that we have to deal simply with the resulting ions. The NO_3^{-} ion has been shown to be non-poisonous, so that in this case also the toxic action must be due to the $^{+}NO^{+}$ ions and to the $^{+}Co^{+}$ ions.

The small amount of ionic Ni and Co necessary to kill the roots is shown below:

PISUM SATIVUM.

Nickel—$\frac{1}{25000}$ mol.=1 part Ni to 435,374 H_2O.
Cobalt—$\frac{1}{12500}$ mol.=1 part Co to 217,687 H_2O.

ZEA MAIS.

Nickel—$\frac{1}{25000}$ mol.=1 part Ni to 435,374 H_2O.
Cobalt—$\frac{1}{32000}$ mol.=1 part Co to 54,421 H_2O.

Even in the case of the cobalt and *Zea Mais*, which shows the greatest concentration for poisoning, the amount of ionic Co is very small when compared with the amount of H_2O.

6. Silver Salts.

In testing the toxic action of silver two salts were used, silver sulfate and silver nitrate. For these experiments the same two seedlings were used. The results obtained for the seedlings of *Pisum sativum* are given in the following table:

PISUM SATIVUM.

Silver Salts.		$\frac{1}{51200}$ equiv.	$\frac{1}{102400}$ equiv.	$\frac{1}{204800}$ equiv.	$\frac{1}{409600}$ equiv.	$\frac{1}{819200}$ equiv.
Ag_2SO_4	1st 24 hours	..	..	8.25 mm	12.25 mm	11.25 mm
	2d 24 hours	..	..	11.75 "	8.5 "	14.25 "
$AgNO_3$	1st 24 hours	..	..	5.5 "	7.0 "	9.5 "
	2d 24 hours	..	..	4.5 "	7.5 "	10.5 "

The solutions here are expressed in equivalents of the toxic ion, since in the Ag_2SO_4 if we had the same fraction of a gram-molecule as in $AgNO_3$, the solution would contain twice as many silver ions. The dilutions were made as follows for Ag_2SO_4:

25cc of $\frac{1}{100}$ mol. to 400cc = $\frac{1}{1600}$ mol.
25cc of $\frac{1}{1600}$ mol. to 400cc = $\frac{1}{25600}$ mol. = $\frac{1}{128000}$ equiv.
100cc of $\frac{1}{25600}$ mol. to 400cc = $\frac{1}{102400}$ mol. = $\frac{1}{51200}$ equiv.
100cc of $\frac{1}{102400}$ mol. to 200cc = $\frac{1}{204800}$ mol. = $\frac{1}{102800}$ equiv., etc.

The dilutions for $AgNO_3$ were made as follows:

10cc of $\frac{1}{2}$ mol. to 1000cc = $\frac{1}{200}$ mol.
25cc of $\frac{1}{200}$ mol. to 200cc = $\frac{1}{1600}$ mol.
25cc of $\frac{1}{1600}$ mol. to 400cc = $\frac{1}{25600}$ mol.
100cc of $\frac{1}{25600}$ mol. to 200cc = $\frac{1}{51200}$ mol., etc.

In the first two dilutions no growth whatever occurred for the entire period and at the end of the experiment the roots were quite rigid, but not more so than in the ordinary seedlings grown under normal conditions. In the last three dilutions considerable growth was observed, so that the killing point for the silver salts is placed at $\frac{1}{102400}$ equivalents.

ZEA MAIS.

Silver Salts.		$\frac{1}{51200}$ equiv.	$\frac{1}{102400}$ equiv.	$\frac{1}{204800}$ equiv.
Ag_2SO_4	1st 24 hours..	1 mm	5 mm	17 mm
	2d 24 hours..	.....	...	12 "
$AgNO_3$	1st 24 hours..	1.5 mm	4 mm	11.25 "
	2d 24 hours..	.....	...	9.25 "

The results of the experiments for the seedlings of *Zea Mais* are given in the preceding table.

For the seedlings of *Zea Mais* it was only necessary to use three dilutions. In the first two of these the roots showed a slight growth during the first twenty-four hours, but no further growth was shown by the second measurement. In the $\frac{1}{204800}$ equiv. solution the growth continued for the entire period, so that here, as in the case of *Pisum sativum* experiments, the killing point is shown to be the $\frac{1}{102400}$ equiv. solution. Here also the roots which were killed remained quite rigid.

In Ag_2SO_4 the dissociation will be into two Ag^+ ions and $^-SO_4^-$ ions. The $AgNO_3$ will dissociate to form Ag^+ ions and $^-NO_3^-$ ions. It has already been shown in several cases that the $^-SO_4^-$ ions and NO_3^- ions are without any toxic action. Now since dissociation is practically complete in the dilutions used, only the ions are to be considered, and the non-poisonous character of the electro-negative ions leaves the Ag^+ ions to produce the toxic effect.

The extremely small amount of ionic silver necessary to kill the root may be expressed as follows:

Both seedlings killed by $\frac{1}{102400}$ eq.=1 part Ag to 948,148 H_2O. According to the above the silver ion is somewhat more poisonous than the copper ion.

9. Mercury.

Experiments were performed with the seedlings of *Pisum sativum* and *Zea Mais* and a single mercury salt, $HgCl_2$. The results of these experiments are given in the following table:

CORROSIVE SUBLIMATE.

$HgCl_2$		$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.	$\frac{1}{204800}$ mol.	$\frac{1}{409600}$ mol.
Pisum sativum	1st 24 hrs	...	2mm	2.25mm	3.75mm	5.75mm	4.5mm
	2d 24 hrs	...	....	.....	.....	7.25 "	4 "
Zea Mais	1st 24 hrs	2mm	7.5mm	19mm	14.5mm	.....	....
	2d 24 hrs	...	10	28	10.5 "	.....	....

The dilutions were made from the $\frac{1}{100}$ molecule solution the same as for the Ag_2SO_4. In the first three dilutions used for the seedlings of *Pisum sativum* a growth of a few millimeters occurred during the first twenty-four hours, but the second measurement showed no further growth. Those roots which were killed remained rigid, but were somewhat discolored at the end of the experiment. In the last two dilutions growth continued throughout the experiment, so that the killing point for the seedlings of *Pisum sativum* is shown to be the $\frac{1}{102400}$ gram-molecule solution. For the seedlings of *Zea Mais* the $\frac{1}{51200}$ and $\frac{1}{102400}$ gram-molecule was first used, but in both of these growth resulted, so two more concentrated solutions were used, which showed the killing point to be the $\frac{1}{12800}$ gram-molecule solution. This, then, shows that the seedlings of *Zea Mais* are able to withstand a much greater amount of mercury than the *Pisum* seedlings.

The $HgCl_2$ will dissociate to form $^{+}Hg^{+}$ ions and two Cl^{-} ions, and at the degree of concentration used the dissociation will be practically complete, so we have to deal simply with $^{+}Hg^{+}$ ions and Cl^{-} ions. The Cl^{-} ions have been shown to be non-poisonous, so the toxic effect must be due to the ionic mercury. The amount of ionic mercury necessary to kill the plants may be expressed as follows:

Pisum sativum: seedlings killed by $\frac{1}{102400}$ mol. = 1 part Hg to 510,978 H_2O.

Zea Mais: seedlings killed by $\frac{1}{12800}$ mol. = 1 part Hg to 63,872 H_2O.

8. Potassium Cyanide.

The effect of CN on the roots of *Pisum sativum* and *Zea Mais* seedlings was tested by solutions of KCN. The results obtained with different solutions are shown in the table on next page.

For the *P. sativum* seedlings no growth whatever occurred in the $\frac{1}{1600}$ and $\frac{1}{3200}$ gram-molecule solutions, while in the $\frac{1}{6400}$ gram-molecule solution growth was noted during the first twenty-four hours but no further growth for the second measurement.

In all of the solutions by which growth was inhibited the roots were quite rigid at the end of the experiment. In the last two dilutions growth was noted for the entire period, so the killing point is shown to be the $\frac{1}{6400}$ gram-molecule solution. The seedlings of *Zea Mais* were started in the $\frac{1}{3200}$ gram-molecule solution which completely inhibited the growth, while the two next dilutions allowed growth to continue, so that here the killing point is shown to be the $\frac{1}{3200}$ gram-molecule solution showing the *Zea Mais* to be somewhat more resistant than the *P. sativum*.

POTASSIUM CYANIDE.

KCN		$\frac{1}{1600}$ mol.	$\frac{1}{3200}$ mol.	$\frac{1}{6400}$ mol.	$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.
P. sativum	1st 24 hours	....	....	1.25 mm	3 mm	2.5 mm
	2d 24 hours	....	....	....	2 "	3 "
Z. Mais..	1st 24 hours		....	2.5 "	3 "	
	2d 24 hours		....	7.5 "	6 "	

The KCN will dissociate to form K^+ ions and CN^- ions, and the dissociation is nearly complete. Since we are dealing here with a potassium salt of HCN and quite dilute solutions, the amount of undissociated KCN will not be very great. At the dilutions used the K^+ ion would not produce any toxic action, so the poisonous quality of the KCN solutions must be due principally to the CN^- ion and to a slight extent to the undissociated KCN, the effect of which will decrease as the dilutions become greater.

9. Potassium Ferro- and Ferri-cyanides.

Experiments were performed with the seedlings of *P. sativum* and *Zea Mais* and potassium ferro- and potassium ferri-cyanide.

In the $\frac{1}{25}$ and $\frac{1}{50}$ gram-molecule solutions of $K_4Fe(CN)_6$ the roots were killed, no growth whatever resulting. In $\frac{1}{100}$ molecule solution growth was observed during the first twenty-four hours, but none afterward. In the $\frac{1}{200}$ and $\frac{1}{400}$ gram-molecule solution growth continued for the entire period. In the $K_3Fe(CN)_6$, the seedlings were set first in the $\frac{1}{100}$ molecule solution in which no

growth occurred. The two next weaker solutions allowed the seedlings to grow. The killing point may be placed, then, at $\frac{1}{100}$ gram-molecule. Those roots which were killed remained rigid, but were somewhat discolored. In the weaker solutions which did not entirely inhibit the growth a retardation of the growth is apparent.

The results of the experiments with *P. sativum* are given in the following table:

PISUM SATIVUM.

Cyanides.		$\frac{1}{250}$ mol.	$\frac{1}{500}$ mol.	$\frac{1}{1000}$ mol.	$\frac{1}{2000}$ mol.	$\frac{1}{4000}$ mol.
$K_4Fe(CN)_6$	1st 24 hours	....	....	1 mm	2.25 mm	7.5 mm
	2d 24 hours	....	....	....	.75 "	5 "
$K_3Fe(CN)_6$	1st 24 hours			....	5 "	7 "
	2d 24 hours			....	3 "	4 "

The results of the experiments with *Zea Mais* are given in the following table:

ZEA MAIS.

Cyanides.		$\frac{1}{250}$ mol.	$\frac{1}{500}$ mol.	$\frac{1}{1000}$ mol.	$\frac{1}{2000}$ mol.
$K_4Fe(CN)_6$	1st 24 hours	....	1.5 mm	2.5 mm	6.75 mm
	2d 24 hours	....	....	....	7.25 "
$K_3Fe(CN)_6$	1st 24 hours	....	1.5 "	8.25 "	15.25 "
	2d 24 hours	....	....	....	3.75 "

In both of the salts no growth occurred in the $\frac{1}{250}$ molecule solution. In the $\frac{1}{500}$ mol. and $\frac{1}{1000}$ mol. solutions growth was noted for the first twenty-four hours but none afterwards. The $\frac{1}{2000}$ mol. solution showed growth for the entire period, so that here as in the case of the *P. sativum* seedlings the killing point is the $\frac{1}{100}$ gram-molecule solution.

In the case of both salts the dissociation will be in the form of K^+ ions and $Fe(CN)^-$ ions, the only difference being the fact that whereas $K_4Fe(CN)_6$ solutions contain four K ions the $K_3Fe(CN)_6$ solutions contain three K ions. For the dilutions used the dissociation is not complete.

For the $K_4Fe(CN)_6$ at 18° C. and of $\frac{1}{32}$ gram-molecule strength about $\frac{15}{26}$ of the molecules will be broken up, and for a $\frac{1}{512}$ gram-molecule solution about $\frac{23}{26}$ of the entire number of molecules will be split up. For the $K_3Fe(CN)_6$ at 18° C. and of $\frac{1}{96}$ gram-molecule strength, about $\frac{18}{23}$ of the total number of molecules will be dissociated.[14] The solutions used will then contain a certain number of undissociated molecules besides the K^+ ions and the $Fe(CN)_6^-$ ions. The K^+ ions have already been mentioned as non-poisonous at these dilutions, so the toxic action must be referred to the $Fe(CN)_6^-$ ions and to some extent to the undissociated molecules.

The much greater strength of solutions which the seedlings are able to withstand in the above experiments over that for the KCN, show that the CN has lost its toxic action to a great extent by combining with the Fe to form the $Fe(CN)_6$ ion.

The roots of *P. sativum* were killed by the $\frac{1}{6400}$ KCN, while it took $\frac{1}{100}$ potassium ferro- or ferri-cyanide. The molecule of the potassium ferro- or ferri-cyanides contained six times as much cyanogen, hence it required 384 times as much cyanogen in the form of the $Fe(CN)_6$ ion to produce the same effect. The roots of *Zea Mais* were killed by the $\frac{1}{3200}$ KCN, while it took $\frac{1}{100}$ gram-molecule of $K_4Fe(CN)_6$ or $K_3Fe(CN)_6$ to produce the same effect, or 192 times as much CN in the form of the $Fe(CN)_6^-$ ion.

10. Silver Nitrate + 3KCN.

Some experiments were also performed to test the action of $AgNO_3 + KCN$ upon the growth of the same seedlings as had been used before. The results are given below:

		$\frac{1}{12800}$ mol.	$\frac{1}{25600}$ mol.	$\frac{1}{51200}$ mol.	$\frac{1}{102400}$ mol.	$\frac{1}{204800}$ mol.
P. sativum	1st 24 hrs...	2.5mm	3mm	3mm	6mm	2.5mm
	2d 24 hrs...	....	.....	3.5	2.5	4
Z. Mais	1st 24 hrs...	1.5	3.25	6	8.25	....
	2d 24 hrs...	....	3.25	2	5.25	....

[14] Ostwald, Chemische Energie 739.

For the *P. sativum* seedlings growth occurred in the first two dilutions for the first twenty-four hours only. In the next dilutions growth continued for the entire period. For *Zea Mais* growth was noted in the first dilution for the first twenty-four hours, but not afterwards, while in the following dilutions growth continued for the entire period. Those roots which were killed remained rigid.

The solutions were mixed upon Ag as a base, and the following action will show what the solutions contain:

$$AgNO_3 + 3KCN = KNO_3 + K(AgCN_2) + KCN.$$

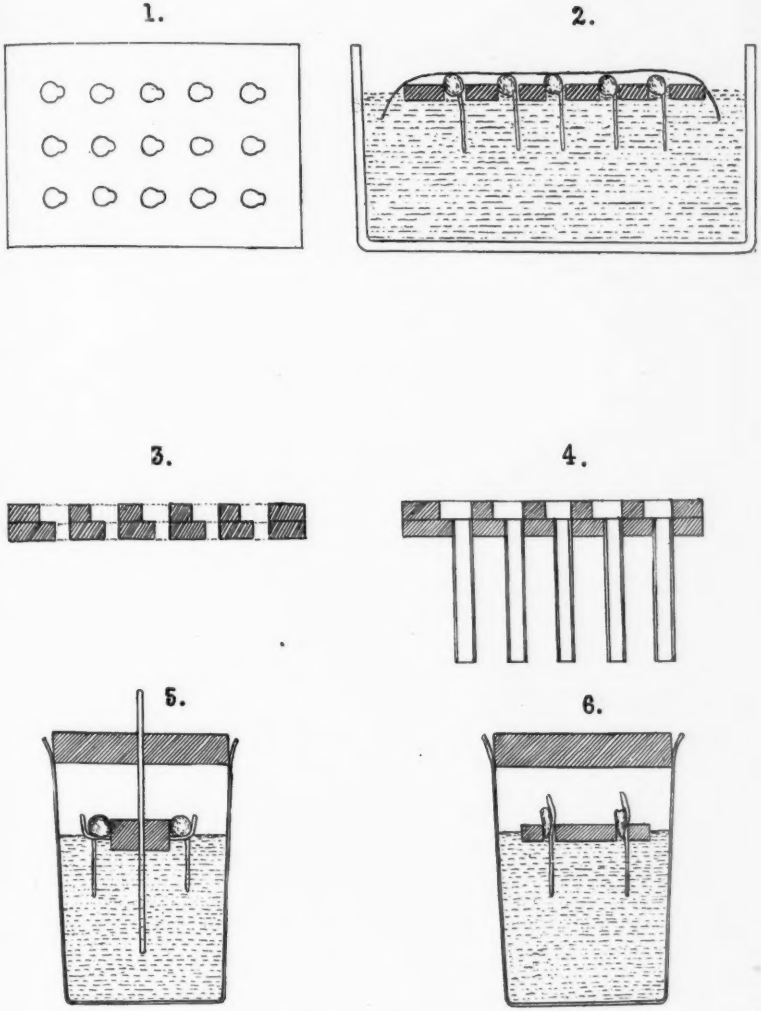
At the dilutions used the KNO_3 is without effect. The $K(AgCN_2)$ will dissociate to form K^+ ions and $AgCN_2^-$ ions; the KCN to K^+ ions and CN^- ions.

The above experiments show that more silver is required to produce poisoning when present in the form of $AgCN_2^-$ ions, than when present as the simple Ag ion: four times as much for the *P. sativum* seedlings and eight times as much for *Zea Mais* seedlings.

A comparison of the results obtained by myself with those of True and Kahlenberg[15] is given in the following table. The dilutions given just allowed growth.

Name of Compound	P. sativum	Z. Mais	L. albus.
HCl	$\frac{1}{12800}$ eq.	$\frac{1}{3200}$ eq.	$\frac{1}{6400}$ eq.
H_2SO_4	" "	" "	" "
HNO_3	" "	" "	" "
HBr	" "	" "	" "
$C_2H_4O_2$	$\frac{1}{3200}$ "	$\frac{1}{400}$ "	$\frac{1}{1600}$ "
$CuCl_2$	$\frac{1}{51200}$ "	$\frac{1}{102400}$ "	$\frac{1}{25000}$ "
$CuSO_4$	" "	" "	" "
$Cu(C_2H_3O_2)_2$	" "	" "	" "
$NiSO_4$	$\frac{1}{51200}$ "	$\frac{1}{51200}$ "	$\frac{1}{25000}$ "
$Ni(NO_3)_2$	" "	" "	.....
$CoSO_4$	$\frac{1}{25000}$ "	$\frac{1}{6400}$ "	$\frac{1}{12800}$ "
$Co(NO_3)_2$	" "	" "	" "
$AgNO_3$	$\frac{1}{204800}$ "	$\frac{1}{204800}$ "	$\frac{1}{204800}$ "
Ag_2SO_4	$\frac{1}{204800}$ "	" "	" "
$HgCl_2$	$\frac{1}{204800}$ "	$\frac{1}{51200}$ "	$\frac{1}{12800}$ "
KCN	$\frac{1}{12800}$ "	$\frac{1}{6400}$ "	$\frac{1}{6400}$ "
$K_4Fe(CN)_6$	$\frac{1}{200}$ "	$\frac{1}{200}$ "	$\frac{1}{200}$ "
$K_3Fe(CN)_6$	" "	" "	" "

[15] BOT. GAZ. 22:81. 1896.



HEALD on EFFECT of DILUTE SOLUTIONS.

11. Conclusion.

1. In nearly all of the seedlings used quite a wide range in the sensibility to the same substance is to be noted. This is especially noticeable in the results obtained for the acids. In some of the salts, as silver salts and $K_4Fe(CN)_6$ and $K_3Fe(CN)_6$, all three of the plants were killed by the same solution.

2. Throughout the whole series of acids and salts used I have shown that the toxic action was due to the ions into which the substances split up in great dilutions. In some cases dissociation was not complete and the effect of the undissociated substance had to be taken into consideration.

3. In all cases, except KCN, $K_4Fe(CN)_6$ and $K_3Fe(CN)_6$, it was the electro-positive or cathion which produced the toxic action. In the three substances mentioned above it was the electro-negative or anions which produced the toxic action.

4. In the cases investigated, compound ions, which contain elements that have a very high toxic action, lose their toxic action to some extent by being combined. This may take place where a comparatively harmless ion unites with one of high toxic value to form a compound ion, or where two ions of high toxic value are associated in a compound ion.

The theory of dissociation in dilute solutions has thus thrown light upon the physiological action of different substances, and the theory has itself been strengthened by these experiments upon living subjects. The results obtained by Kahlenberg and True have been confirmed throughout all of my experiments.

I wish here to thank Dr. Kahlenberg for aid and many valuable suggestions, and for the kindly interest which he has taken in my work.

University of Wisconsin, Madison.

FLOWERS AND INSECTS. XVII.

CHARLES ROBERTSON.

For a more extended title of this series I have adopted that of "Contributions to an account of the ecological relations of the entomophilous flora and the anthophilous insect fauna of the neighborhood of Carlinville, Illinois." The following papers should be regarded as parts of the same series: Flowers and Insects: Umbelliferæ. *Trans. St. Louis Acad. Science* **5:** 449–460. 1890; Asclepiadaceæ to Scrophulariaceæ, *ibid.* **5:** 569–598. 1891; Labiatæ. *ibid.* **6:** 101–131. 1892. (no. 4); Rosaceæ and Compositæ, *ibid.* **6:** 435–480. 1894. (no. 14); Flowers and Insects, *ibid.* **7:** 151–179. 1896. (no. 6); The Philosophy of Flower Seasons, American Naturalist **29:** 97–117. 1895. The cases of some plants, such as those observed in Florida, which properly do not come under the title, are distinctly specified.

The present paper discusses a number of plants, which, although not akin, should be compared because of the influence which their greenish yellow colors have been considered to have in determining the character of the insect visits.

CAULOPHYLLUM THALICTROIDES (L.) Michx. is a perennial plant, rather frequent in rich woods, and blooming a short time, April 23d to May 7th. The stems grow several decimeters high and bear single small loose panicles of yellowish green flowers. The flowers expand horizontally about 10^{mm}, and, I think, remain open at night. Each of the six sepals has, lying upon its base, a short petal which is somewhat kidney-shaped, being expanded into a nectar gland as wide as the sepal. The style is very short and is tipped by a small stigma, which is receptive before the anthers dehisce. From the shortness of the stamens, as well as their later dehiscence, I think that spontaneous self-pollination does not occur. According to the views usually held with regard to

flowers of like color and nectar exposure, we might expect a strong predominance of flies. My observations do not show this.

With the exception of no. 18, taken April 23d, the following list was observed on May 1st:

HYMENOPTERA — *Andrenidæ*: (1) Halictus confusus Sm. ♀, s. & c. p.; (2) H. 4-maculatus Rob. ♀, s.; (3) Augochlora viridula Sm. ♀, s.; *Braconidæ*: (4) Bracon trifolii Ashm.; (5) B. veronniæ Ashm.; (6) Microgaster gelechiæ Riley, ab.; (7) Opius ruficeps Prov.; (8) Dacnusa flavicincta Ashm.; *Chalcididæ*: (9) Prosacantha illinoensis Ashm. (MS)—all s.

DIPTERA—*Mycetophilidæ*: (10) Dynatosoma thoracica Coq. (MS); *Empidæ*: (11) Rhamphomyia piligeronis Coq. (MS); *Syrphidæ*: (12) Chilosia capillata Lw.; (13) Melanostoma obscurum Say; (14) Rhingia nasica Say; *Anthomyidæ*: (15) Hylemyia plumosa Coq. (MS); (16) Mydæa flavipes Coq. (MS); *Oscinidæ*: (17) Chlorops trivialis Lw.— all s.

COLEOPTERA—*Mordellidæ*: (18) Mordellistena biplagiata Hel.; *Curculionidæ*: (19) Idiostethus subcalvus Casey, both s.

PTELEA TRIFOLIATA L. — According to Hildebrand (1) and Kerner (3), the flowers are staminate and perfect. Urban (2) indicates that *Ptelea* is dicœcious, and that self-pollination is impossible. As far as I have observed, it has appeared that this species is dicœcious. I could find no perfect flowers.

The greenish white blossoms expand from 10 to 15^{mm} and are crowded in compound cymes, which are nearly level topped and form convenient resting places for insects. In both forms nectar is secreted by the gynophore and is slightly concealed by the hairy bases of the filaments.

The following table shows the kinds of insects taken on *Xanthoxylum Americanum* and *Ptelea trifoliata*, the former blooming from April 12th to 28th and the latter from May 8th to June 12th:

	Other Hymenoptera	Apidæ	Andrenidæ	Diptera	Lepidoptera
Xanthoxylum Americanum (39)	0	6	19	13	1
Ptelea trifoliata (51)	12	1	22	14	2

The difference in Apidæ may be partly on account of the former having the nectar more concealed, but is mainly, I think, on account of the blooming time. At any rate, three of the Apidæ taken on *Xanthoxylum* have finished their flight before

Ptelea goes out of bloom. Of the twelve species of lower Hymenoptera taken on *Ptelea*, not one is flying during the period of *Xanthoxylum*. The inflorescence of *Ptelea* is more favorable for their visits.

The principal pollinators are Andrenidæ. May 28th, 30th and June 1st, 4th and 8th the following list was observed:

HYMENOPTERA—*Apidæ*: (1) Apis mellifica L. ☿, s., freq.; *Andrenidæ*: (2) Halictus coriaceus Sm. ♀, s.; (3) H. ligatus Say ♀, s.; (4) H. lerouxii Lep. ♀, s.; (5) H. cressonii Rob. ♀, s. & c. p.; (6) H. pilosus Sm. ♀, s.; (7) H. confusus Sm. ♀, s. & c. p.; (8) H. stultus Cr. ♀, s. & c. p.; (9) H. tegularis Rob. ♀, s. & c. p.; (10) Agapostemon radiatus Say, ♀, s.; (11) Augochlora pura Say, ♀ s.; (12) Andrena roberteonii D. T., ♀, s. & c. p., freq.; (13) A. platyparia Rob. ♂♀, s. & c. p.; (14) A. cressonii Rob. ♀, s.; (15) A. bipunctata Cr. ♀, s. & c. p., freq.; (16) A. nuda Rob. ♀, s. & c. p.; (17) A. rugosa Rob. ♀, s.; (18) A. spiræana Rob. ♂♀, s.; (19) A. hippotes Rob. ♀, s. & c. p., ab.; (20) A. claytoniæ Rob. ♀, s., freq.; (21) A. cratægi Rob. ♀, s. & c. p.; (22) Sphecodes confertus Say ♀, s., freq.; (23) Prosopis modesta Say, ♂, s.; *Eumenidæ*: (24) Eumenes fraternus Say, s.; (25–27) Odynerus spp., s.; (28) O. unifasciatus Sauss., s.; (29) O. tigris Sauss., s.; (30) O. foraminatus Sauss., s.; *Crabronidæ*: (31) Oxybelus illinoensis Rob. (MS), s.; *Philanthidæ*: (32) Cerceris compar Cr., s.; *Sphecidæ*: (33) Ammophila vulgaris Cr., s.; *Scoliidæ*: (34) Elis confluenta Say, s.; *Chalcididæ*: (35) Leucospis affinis Say, s.

DIPTERA—*Stratiomyidæ*: (36) Stratiomyia meigenii Wd.; *Conopidæ*: (37) Conops brachyrhynchus Mcq., s.; (38) Myopa vesiculosa Say, s.; *Syrphidæ*: (39) Sphærophoria cylindrica Say, s.; (40) Myolepta nigra Will., s.; (41) Volucella vesiculosa F., s.; (42) Mallota cimbiciformis Fil. f. bautias Wlk., s.; (43) Syritta pipiens L., s.; *Tachinidæ*: (44) Trichopoda sp., s.; (45) Jurinia smaragdina Mcq., s.; (46) J. apicifera Wlk., s.; (47) Micropalpus fulgens Mg., s.; *Muscidæ*: (48) Lucilia cornicina F., s.; *Anthomyidæ*: (49) Phorbia fusciceps Zett.

LEPIDOPTERA—*Rhopalocera*: (50) Neonympyha eurytris F., s.; *Heterocera*: (51) Alypia octomaculata Hbn.

Trelease (MS notes) captured the following insects on the flowers:

HYMENOPTERA—*Apidæ*: (1) Psithyrus (Apathus) laboriosus F., ♀; (2) Nomada sp.; *Andrenidæ*: (3) Halictus pilosus Sm., ♀; (4) Andrena pruni Rob., ♀; (5) A. illinoensis Rob., ♀; (6) A. cratægi Rob., ♀; (7) Agapostemon viridulus F., ♀; (8) Sphecodes confertus Say, ♀; (9) Prosopis modesta Say, ♀; *Vespidæ*: (10) Vespa germanica F.; (11) Polistes metricus Say; *Eumen-*

idæ: (12) Odynerus albophaleratus Sauss.; *Crabronidæ*: (13) Oxybelus 4-notatus Say; *Philanthidæ*: (14) Cerceris pedalis Cr.

COLEOPTERA—*Coccinellidæ*: (15) Analia bipunctata L.; *Dermestidæ*: (16) Anthrenus scrophulariæ L.; *Lampyridæ*: (17) Chauliognathus pennsylvanicus De G.; and other insects which I have not seen, probably flies.

On the literature of *Ptelea* see:

(1) Hildebrand, Geschlechtsvertheilung bei den Pflanzen, 11:26. 1867. —(2) Urban, Zur Biologie und Morphologie der Rutaceen, Jahrb. bot. Gartens Berlin 2:397–8. 1883. (Just 11¹:497.)—(3) Kerner, Pflanzenleben 2:295. 1891. (Just 18¹:486.)

RHAMNUS L.—The species which have been studied are dicœcious—*R. cathartica* (Darwin 7), *saxatilis* and *tinctoria* (Kerner 19)—or with flowers perfect, as in *R. Frangula* and *pumila* (Müller 3, 11), the former being proterandrous and the latter homogamous. *R. cathartica* has four sub-forms (Darwin 7), and *Frangula* shows a tendency to produce a long and short-styled form, as in our *R. lanceolata* (Schulz 17).

The flowers are small, greenish, with easily accessible nectar and have been considered to be adapted to flies (Delpino 5, Müller 12, 13), but this does not seem to be supported by sufficient data. Still more extreme is the limitation of the proper visitors to flesh-flies (Kerner 19). My list of visitors of *R. lanceolata* resembles those of white or yellow flowers with similarly placed nectar and blooming about the same time. The results of the observation of different species in separate regions is given in the following table:

	Apidæ	Andrenidæ	Other Hymenop	Diptera	Coleoptera	Total
Rhamnus lanceolata, Illinois	4	23	3	22		52
R. Frangula, Low Germany, Müller (3, 10)	2	1	2	1		6
R. Frangula, Flanders, MacLeod (20)	2			1	1	4
R. pumila, Alps, Müller (11)			4	8	5	17

RHAMNUS LANCEOLATA Pursh.—According to Darwin (7), this species is dimorphous, but not properly heterostyled. The small trees grow as high as three or four meters and bear

numerous greenish flowers which appear with the leaves. The stamens are exserted so that the pollen may be eaten by Syrphidæ or collected by Andrenidæ, but the style is short and included. The calyx tube is about 2^{mm} deep and 1^{mm} wide. Consequently the nectar, which is secreted by a disk lining the tube, is readily accessible to small, short-tongued insects. From their structure and blooming time, April 23d to May 10th, the flowers seem to be specially adapted to Andrenidæ, but they are also visited less abundantly and less efficiently by flies. On the 1st and 2d of May I captured the following visitors:

HYMENOPTERA—*Apidæ:* (1) Apis mellifica L. ☿, s., one; (2) Bombus americanorum F. ♀, s.; (3) Ceratina dupla Say ♂, s.; (4) Nomada maculata Cr. ♀, s.; *Andrenidæ:* (5) Halictus foxii Rob. ♀, s. and c. p., freq.; (6) H. arcuatus Rob. ♀, s. and c. p.; (7) H. forbesii Rob. ♀, s. and c. p.; (8) H. lerouxii Lep. ♀, s. and c. p.; (9) H. fasciatus Nyl. ♀, s. and c. p., ab.; (10) H. pilosus Sm. ♀, s. and c. p., freq.; (11) H. confusus Sm., ♀, s. and c. p., freq.; (12) H. pruinosus Rob. ♀, s.; (13) H. illinoensis Rob. ♀, s.; (14) H. zephyrus Sm. ♀, s. and c p.; (15) H. stultus Cr. ♀; (16) Agapostemon radiatus Say ♀, s., freq.; (17) Augochlora viridula Sm. ♀, s.; (18) A. pura Say ♀, s. and c. p., freq.; (19) A. labrosa Say ♀, s. and c. p.; (20) Andrena erythrogastra Ashm. ♂, s.; (21) A. mandibularis Rob. ♀, s.; (22) A. nasonii Rob. ♀, s. and c. p.; (23) A. cressonii Rob. ♂♀, s. and c. p., ab.; (24) A. bipunctata Cr ♂, s.; (25) A. ziziæ Rob. ♂♀, s. and c. p., freq.; (26) A. cratægi Rob. ♂, s.; (27) Sphecodes mandibularis Cr. ♀, s.; *Eumenidæ:* (28) Eumenes fraternus Say, s.; (29) Odynerus tigris Sauss., s.; *Tenthredinidæ:* (30) Dolerus arvensis Say, s.

DIPTERA—*Empidæ:* (31) Rhamphomyia priapulus Lw.; *Syrphidæ:* (32) Pipiza femoralis Lw.; (33) Chrysogaster nitida Wd.; (34) Syrphus ribesii L.; (35) S. americanus Wd.; (36) Xanthogramma felix O. S.; (37) Allograpta obliqua Say, freq.; (38) Mesograpta geminata Say, ab.; (39) M. marginata Say; (40) Sphærophoria cylindrica Say, freq.; (41) Helophilus similis Mcq.; (42) Syritta pipiens L.; *Tachinidæ:* (43) Cyphocera fuesta V. d. W.; *Sarcophagidæ:* (44) Cynomyia mortuorum L.; (45) Sarcophaga ægra Wlk.; (46) S. cimbicis Twns.; *Muscidæ:* (47–48) Lucilia spp.; (49) L. latifrons. Schin.; *Cordyluridæ:* (50) Scatophaga squalida Mg.; *Anthomyidæ:* (51) Phorbia acra Wlk.; (52) P. fusciceps Zett.—all s. or f. p.

On the literature of *Rhamnus* see:

(1) Darwin, on the two forms, or dimorphic condition, in the species of *Primula*, and on their remarkable sexual relations; Journ. Linn. Soc. Bot. 6:95. 1862—*R. lanceolata.* (2) Hildebrand, Geschlechtsvertheilung bei den Pflanzen 9:40. 1867—*R. cathartica, lanceolata.* (3) Müller, Befruchtung

der Blumen 152. 1873—*R. Frangula.* (4) Kerner, Die Schutzmittel des Pollens 56. 1873. (5) Delpino, Ulteriori osservazioni, pt. II, fasc. 2:20, 214, 300, 316, Att. Soc. Ital. Sci. Nat., Milano **16**:168. 1873; **17**:——. 1874 —*R. cathartica, Frangula, alterna* (Just **2**:895). (6) Lubbock, British wild flowers in relation to insects 79. 1875—*R. cathartica, Frangula, lanceolata.* (7) Darwin, Forms of flowers, 273–7. 1877—*R. cathartica, lanceolata, Frangula.* (8) Bonnier, Les Nectaires, Ann. Sci. Nat. Bot. **8**:39. 1878. *R. Frangula, alpina,* inconspicuous flowers abundantly visited. (9) Dodel-Port, Die Liebe der Blumen **4–5**:185–240. 1880—*R. cathartica* (Just **8**[1]:183). (10) Müller, Weitere Beobachtungen, II, Verh. naturhist. Ver. preuss. Rheinl. u. Westf. 212. 1879—*R. Frangula.* (11) Müller, Alpenblumen 169–71. 1881—*R. pumila.* (12) Müller, Geschichte der Erklärungsversuche in Bezug auf die biologische Bedeutung der Blumenfarben, Kosmos **12**:125, N., 1882 (Just **9**[1]:506). (13) Müller, Die biologische Bedeutung der Blumenfarben, Biol. Centralblatt **3**:99, Ap. 1883. (14) Müller, Die Stellung der Honigbiene in der Blumenwelt, III, Deutsche Bienenzeit. **39**:157–61. 1883—*R. pumila,* Apis wanting. (15) Müller, Fertilization of flowers, 163–4. 1883—*R. Frangula, cathartica, lanceolata, pumila.* (16) Kirchner, Flora von Stuttgart und Umgebung, 363–4. 1888—*R. Frangula, cathartica.* (17) Schulz, Beiträge zur Kenntniss der Bestäubungseinrichtungen und Geschlechtsvertheilung bei den Pflanzen, **1**:31. 1888; **2**:61, 185. 1890. Bibliotheca Botanica, 10 und 17—*R. Frangula, cathartica, pumila.* (18) Trelease, North American Rhamnaceæ, Trans., St. Louis Acad. Sci. **5**:359. (19) Kerner, Pflanzenleben, **2**:169, etc. 1891—*R. cathartica, saxatilis, tinctoria.* (20) MacLeod, Over de bevruchting der bloemen in het kempisch gedeelte van Vlaandern, Bot. Jaarbock. **6**:247–9, 438, 1894—*R. Frangula, cathartica.* (21) Loew, Blütenbiologische Floristik **36**:215. 1894—*R. pumila, Frangula, cathartica, saxatilis.*

Rhus L.—The species are said to be polygamous or polygamo-dicœcious. It might be better to call them dicœcious, though of a recent form, for the staminate and pistillate flowers have large rudiments of pistils and stamens, and there is a tendency for them to revert to the perfect condition. Müller (4, 14) and Kerner (16) mention *R. Cotinus* as polygamous; but in Halle and in South Tyrol Schulz (15) found it to be dicœcious, though it appears (Loew[1] 20) that in the former locality he afterwards found polygamous examples. In the manual *R. typhina* is called polygamous, while Müller calls it dicœcious.

[1] In the Floristik, unfortunately, Loew mentions an author without citing any of the separate papers listed under that author's name.

Meehan (6, 18) referring to the fact that *R. copallina*, *venenata* and *Toxicodendron* are variously classed as dicœcious, polygamo-dicœcious, or polygamous, insists that they and *R. cotinoides* are all truly dicœcious. I regard *R. glabra* and *Canadensis* as dicœcious.

In regard to the staminate, perfect, and pistillate flowers of *R. Cotinus*, Müller observes that they decrease in size in the order mentioned, and that, consequently, most insects visit them in the most advantageous order. Schulz failed to confirm the latter observation. In *R. glabra* and *Canadensis*, I think insects prefer the staminate flowers, partly because they are more conspicuous and because they contain pollen as well as nectar, and that the order of their visits is advantageous. However, I do not believe that natural selection has operated in producing the difference, and so hold that it would be erroneous to say that the difference exists to secure the advantage. As a rule stamens are more conspicuous than pistils, and it is quite obvious that a small flower containing five stamens will be more evident than one containing a single pistil. The larger perianth may be explained as existing to support, and at first to protect, this exterior set of organs.

Two effects upon the insect visitors have been attributed to the dull yellow colors of *Rhus*. Müller says that *R. Cotinus*, like all other flowers of a dull yellow color, is almost completely avoided by Coleoptera. The general proposition is denied by Bonnier (9), and Schultz says that it is not true for *R. Cotinus* in the Tyrol, where he found many beetles among the visitors. *Pastinaca*, on which I have taken forty species of beetles, is mentioned by Müller as an example of the same kind.

The idea that the flowers of *Rhus* were specially attractive to flies (macromyiophilous) seems to have originated with Delpino (5). The "Tipo ramnaceo," which he regards as macromyiophilous, includes the greenish yellow species of *Rhus*, *Rhamnus*, *Euonymus*, *Euphorbia*, etc. In a special paper on the biological significance of flower-colors Müller (12) says that greenish yellow colors are frequent in flowers among whose visitors the

larger Diptera predominate. Both authors distinguish these cases from the dark colored flowers, like *Stapelia*, *Asimina*, etc., which they consider to be adapted to flesh flies. The view in regard to the greenish yellow flowers does not seem to have been supported, if not entirely refuted, by subsequent investigations. Kerner's view (16) that these colors are specially attractive to flesh flies was never held either by Delpino or Müller, and so may be considered to be supported neither by authority nor recorded observations. Of the greenish yellow flowers which bloom in my neighborhood I have found a preponderance of general Diptera on none except *Sassafras*. Indeed I expect *Smilax herbacea* and *S. ecirrhata* to show a preponderance of flesh flies, but they differ from the others, and from all of the cases cited by Kerner, in having a scent of carrion.

The following table gives results of observations of insect visitors of *Rhus* in cases in which the species have been identified. The Andrenidae and lower Hymenoptera preponderate over the Diptera. In the Tyrol Schulz saw *R. Cotinus* very abundantly visited by a set of insects which in a general way must resemble my list for *R. glabra* (19).

	Apidæ	Andrenidæ	Other Hymenop	Dipteria	Other insects	Total
Rhus Cotinus — Low Germany — Müller (4,14)	1	3	6	6	1	17
Rhus typhina — Low Germany — Müller (4,14)	1	1	..	..	1	3
Rhus glabra—Illinois (19)	3	16	13	25	1	58
Rhus Canadensis — Illinois (19)	2	21	1	9	..	33

RHUS CANADENSIS Marsh. *R. aromatica* Ait. This is a slender shrub growing on high creek banks, the stems rising from 1 to 2^{m} high. The branchlets are terminated by clusters of about three small, head-like racemes, which measure 8–10^{mm} in length, and appear before the leaves. The flower buds escape from hibernacula whose scales still clasp the bases of the stalks.

The flowers are small, greenish yellow, with short petals. They are quite shallow, the nectar being almost freely exposed. Nectar is secreted by five orange colored glands situated between the bases of the filaments. The staminate flowers have the petals a little longer and more often expanded, so that this form is the more conspicuous. The nectar glands are larger, more triangular and united at base. The pistil is so strongly developed that the flower appears to be perfect. In the pistillate flower the nectar glands are more bilobed. The stamens are of normal form, but greatly reduced in size, and are without pollen. Both forms are abundantly visited by insects.

In the case of *Xanthoxylum Americanum*, which blooms from April 12th to 28th, and *Ptelea trifoliata*, blooming from May 8th to June 12th, we have observed that the lists differ in the absence of the lower Aculeata from *Xanthoxylum*. This was explained as a result of the difference in their blooming time. If we compare *R. Canadensis*—April 4th to 27th—with *R. glabra*—June 8th to 24th—we find the same result. In the former case not one of the lower Aculeata occurring on *Ptelea* flies while *Xanthoxylum* is in bloom. Here we have a similar condition, for *Polistes metricus* is the only one taken on *R. glabra* which is flying during the flower season of *R. Canadensis*. The large inflorescences of *Ptelea* and *R. glabra* form more convenient resting places for these often large straddling insects. The differences in the inflorescences may be accounted for partly by the difference in the composition of the late insect fauna; but the early months, when there is apt to be frost, are not favorable for the development of large flower clusters. Then, too, before the leaves appear, the smaller clusters are sufficiently conspicuous. Other differences in the lists are connected with the blooming time, viz., the advent of *Prosopis*, substitution of two late *Colletes* for the early *C. inaequalis*, and an increase of *Halictus* associated with the decline of the vernal species of *Andrena*.

The following visitors of *R. Canadensis* were taken on April 4th, 10th, 12th and 19th:

HYMENOPTERA—*Apidæ*: (1) Ceratina tejonensis Cr., ♂; (2) Nomada

maculata Cr., ♂♀, freq.; *Andrenidæ*: (3) Halictus sp. ♀; (4) H. foxii Rob., ♀, freq.; (5) H. forbesii Rob., ♀, freq.; (6) H. ligatus Say, ♀; (7) H. cressonii Rob., ♀; (8) H. zephyrus Sm., ♀, freq.; (9) H. stultus Cr., ♀; (10) Agapostemon texanus Cr., ♀; (11) Augochlora pura Say, ♀; (12) Andrena sp. ♂♀, freq.; (13) A. vicina Sm., ♂♀, freq.; (14) A. erythrogastra Ashm., ♀; (15) A. mandibularis Rob., ♂♀, freq.; (16) A. illinoensis Rob., ♀; (17) A. cressonii Rob., ♂; (18) A. bipunctata Cr., ♂♀, freq.; (19) A. rugosa Rob., ♂♀, ab.; (20) A. mariæ Rob., ♂, freq.; (21) A. claytoniæ Rob., ♂♀, ab.; (22) A. forbesii Rob., ♀; (23) Colletes inæqualis Say, ♂, freq.; *Ichneumonidæ*: (24) Lampronota coxalis Ashm. (MS.), ♀, type.

DIPTERA — *Empidæ*: (25) Rhamphomyia priapulus Lw.; *Syrphidæ*: (26) Syrphus americanus Wd., freq.; (27) S. ribesii L.; (28) Eristalis dimidiatus Wd.; *Tachinidæ*: (29) Gonia frontosa Say, freq.; *Sarphagidæ*: (30) Cynomyia mortuorum L.; *Muscidæ*: (31) Lucilia cornicina F., freq.; *Sciamyzidæ*: (32) Tetanocera pictipes Lw.; *Lonchæidæ*: (33) Lonchæa polita Say — all sucking.

On the literature of *Rhus* see:

(1) Hildebrand, Geschlechtsvertheilung bei den Pflanzen **10**. 1867 — *R. Toxicodendron*. (2) Axell, Om anordningarna für de fanerogama växternas befruktning 47. 1869 — *R. Toxicodendron*. (3) Delpino, Altri apparecchi dicogamici recentemente osservati, Nuovo Giorn. Bot. Ital. **2**: 52. 1870. (4) Müller, Befruchtung der Blumen 157–8. 1873. (5) Delpino, Ulteriori osservazioni, Part II, fasc. **2**: 20, 214, 300. 1875, Atti. Soc. Ital. Sci., Milano **16**: 168. 1873; **17**. 1874 (Just. **2**: 882, 895). (6) Meehan, On hermaphroditism in *Rhur cotinus* and in *Rhus glabra*, Proc. A. A. A. S., 1873; B. 73–5. (7) Meehan, On self-fertilization and cross-fertilization in flowers, The Penn Monthly, N. 1876 (Just. **4**: 939). (8) Müller, Das Variiren der Grösse gefärbter Blüthenhüllen und sein Einfluss anf die Naturzüchtung der Blumen, Kosmos **2**: 132–3. 1887 — *R. Cotinus, typhina* (Just. **5**: 740–1). (9) Bonnier, Les Nectaires, Ann. Sci. Nat. Bot. VI, **8**: 71. 1878 — *R. Cotinus*. (10) Patton, Observations on the genus Macropis, Am. Journ. Sci. and Arts III, **18**: 211, 212. 1879 — *R. glabra typhinæ* (Just **7**[1]: 145). (11) Bontroux, Sur l'habitat et la conservation des lévures spontanées, Bull. Soc. Linn. Normandie, III, **6**. 1881 — *R. Cotinus* (Just **13**[1]: 745). (12) Müller, Die biologische Bedeutung der Blumenfarben, Biol. Cent. **3**: 99. 1883 (Just **9**[1]: 506). (13) Müller, Die Stellung der Honigbiene in der Blumenwelt, III, Bienenzeit, Jahrg. **39**: 157–161. 1883 — *R. typhina* (Just **11**[1]: 476). (14) Müller, Fertilization of Flowers, 166–7. 1883. (15) Schulz, Beiträge Zur Kenntniss der Bestäubungseinrichtungen and Geschlechtsvertheilung bei den Pflanzen **2**: 62–4, 186. 1890, Bibliotheca Botanica **17** (Just **18**[1]: 517). (16) Kerner, Pflanzenleben **2**: 192, 297. 1891; Kerner & Oliver **2**: 173, 197, 297. 1895 (Just **17**[1]: 531, 2; **18**[1]: 486). (17) Engler, Anacardiaceæ, Engler u. Prantl, Die nat. Pflanzenfamilien, **73**: 142. 1892 [Th. III, Abth. S] — *R. Cotinus* (Just **20**[1]: 481). (18)

Meehan, Contributions to the life histories of plants, VIII, Proc. Acad. Nat. Sci., Phila., 1892, 369–71 (Just 20[1]:494). (19) Robertson, Flowers and insects, XII, Bot. Gaz. 19:111, 112. 1894. (20) Loew, Blütenbiologische Floristik, 215 — *R. Cotinus.*

SASSAFRAS OFFICINALE Nees. *S. Sassafras* (L.) Karst. Hildebrand (1) observes that the pistillate and staminate flowers each have rudiments of the other set of organs, being what Kerner (2) calls pseudo-hermaphrodite. According to Bentham and Hooker's Genera Plantarum, and Gray's Manual this species is dioecious; and that is what I have always regarded it, though I paid attention to little except the insect visitors. Chapman, in the Flora of the Southern States, calls it dicœciously polygamous, while Kerner calls it polygamous. My observations were made upon trees which I supposed bore only staminate flowers.

The flowers are greenish yellow, expand about 8 or 9[mm], and are arranged in corymbose clusters, which appear with the leaves. There are nine stamens. The three inner ones have at base of each a pair of stalked glands which secrete nectar. The nectar is therefore fully exposed on a convex surface.

There are a number of early flowers with convenient nectar, some of which on account of their greenish yellow color have been supposed to be principally visited by flies. In all except *Caulophyllum* and *Sassafras* the less specialized bees, Andrenidæ, outnumber the flies. *Sassafras* is the only one on which the flies clearly preponderate. In most of the species the nectar tends to collect in shallow cups, which make it very convenient for the Andrenidae, while in *Caulophyllum* and *Sassafras* it is secreted on convex surfaces, which make it more convenient for flies and less convenient for the little bees. However, the exposure of the nectar does not explain why *Sassafras* shows a preponderance of Diptera, but only why it shows more flies than the other greenish yellow flowers blooming about the same time. During the blooming season, April 19th–May 7th, the flowers are exposed to none of the lower aculeate Hymenoptera, except eight species of *Vespa* and *Polistes* and *Priocnemis conicus.* The last is the only one of these taken on the flowers. It happens to be the only one of the *Pompilidæ* flying during the blooming season. Sup-

pose that *Sassafras* bloomed in the last of July, what would there be to keep it from being visited by several of the nineteen species of *Pompilidæ* flying at that time, or by many other short-tongued Aculeata which are then very abundant? In the south the lower Aculeata begin to fly earlier, and I should expect *Sassafras*, and many other early flowers with exposed or slightly concealed nectar, to show an increase in the proportion of these insects as we move in that direction.

The following insects were taken on the flowers on April 27th and 29th:

HYMENOPTERA — *Andrenidæ*: (1) Halictus cressonii Rob., ♀; (2) H. confusus Sm., ♀, s. & c. p.; (3) H. stultus Cr., ♀; (4) Andrena sp. ♀; (5) A. illinoensis Rob., ♂; (6) A. hippotes Rob., ♂; *Pompilidæ*; (7) Priocnemis conicus Say; *Chalcididæ*: (8) Eurytoma sp.; *Ichneumonidæ*: (9) Pimpla annulipes Br.; (10) Idiolespa anilis Grav.; (11) Ophion bifoveolatum Br.; *Tenthredinidæ*: (12) Hylotoma mcleayi Leach; (13) Monophadnus medius Norton.

DIPTERA — *Simulidæ*: (14) Simulium pecuarum Riley; *Bibionidæ*: (15) Bibio pallipes Say, freq.; (16) B. femorata Wd.; *Stratiomyidæ*: (17) Sargus iridis Say; *Empidæ*: (18) Empis compta Coq. (MS); (19) Rhamphomyia ravida Coq. (MS); (20) R. piligeronis Coq. (MS.); (21) R. priapulus Lw., freq.; (22) R. mutapilis Lw., freq.; (23) R. exigua Lw.; *Syrphidæ*: (24) Chilosia versipellis Will., freq.; (25) Chrysogaster nitida Wd.; (26) Platycheirus hyperboreus Staeg.; (27) Syrphus americanus Wd.; *Tachinidæ*: (28) Nemoræa aldrichii Twns.; (29) Gonia frontosa Say; (30) Micropalpus fulgens Mg.; (31) Phorocera edwardsii Will.; *Sarcophagidæ*: (32) Cynomyia mortuorum L., freq.; (33) Sarcophaga sp.; (34) S. cimbicis Twns.; *Muscidæ*: (35) Lucilia sp.; (36) L. cæsar L.; (37) L. cornicina F.; (38) Morellia micans Mcq., freq.; *Anthomyidæ*: (39) Homalomyia prostrata Rossi; (40) Caricea antica Wlk.; (41) Phorbia acris Wlk., ab.; (42) P. fusciceps Zett., ab.; *Cordyluridæ*: (43) Scatophaga squalida Mg.; *Oscinidæ*: (44) Chlorops trivialis Lw.; *Agromyzidæ*: (45) Agromyza latipes Mg.; (46) A. æneiventris Fll.

COLEOPTERA — *Lampyridæ*: (47) Telephorus bilineatus Say, freq.; *Œdemeridæ*: (48) Asclera puncticollis Say.

HEMIPTERA — *Corimelænidæ*: (49) Corimelæna pulicaria Ger. — all only sucking, except No. 2.

On the literature of *Sassafras* see:

(1) Hildebrand, Geschlechtsverteilung bei den Pflanzen 9. 1867. *Laurus Sassafras*: (2) Kerner, Pflanzenleben 2: 297. 1891. Oliver, translation, 288 1895 — *L. Sassafras*.

CARLINVILLE, ILLINOIS.

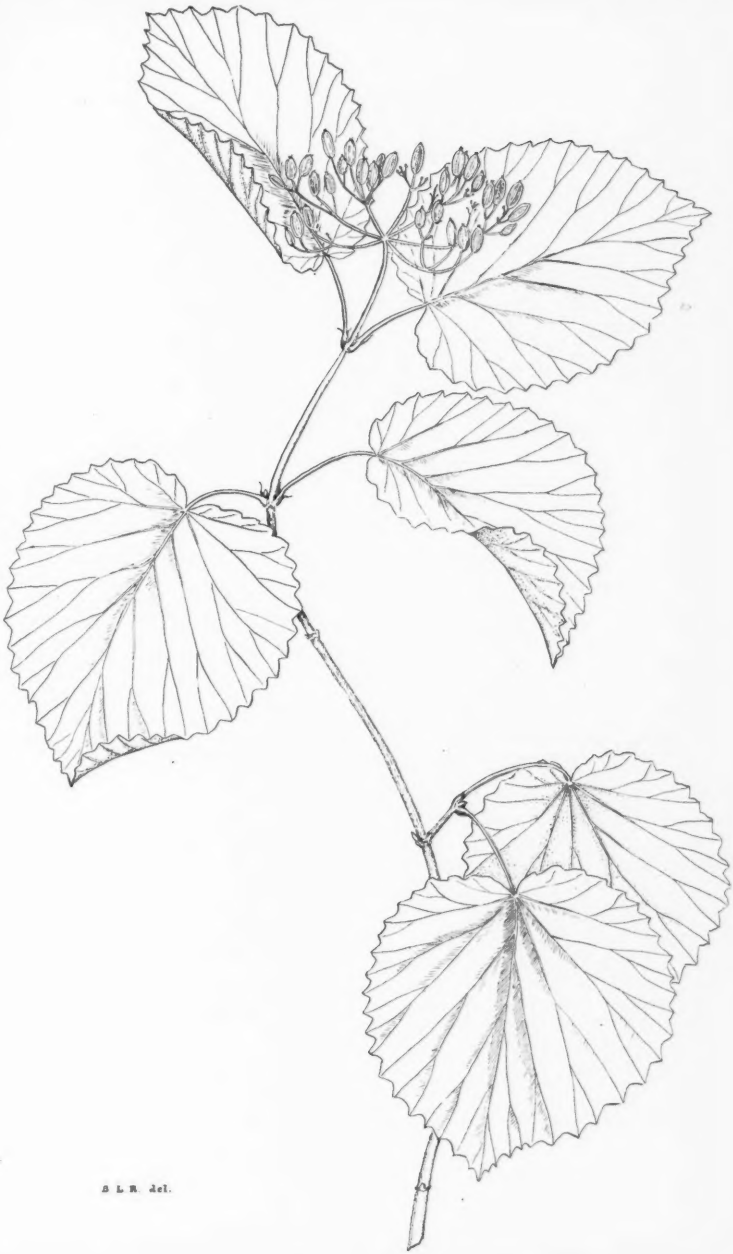
BRIEFER ARTICLES.

A NEW VIBURNUM FROM MISSOURI.

(WITH PLATE VIII.)

Among some herbarium exchanges sent last autumn by Mr. C. H. Demetrio, of Emma, Saline Co., Missouri, to Mr. Deane, was a noteworthy Viburnum, not satisfactorily referable to any described species. The plant had been discovered by Mr. Demetrio near Cole Camp, Benton Co., Missouri, in July, 1894, and appeared most closely related on the one hand to *V. dentatum* L., and on the other to *V. pubescens* Pursh. However, the single fruiting specimen, first received, scarcely warranted description, and Mr. Demetrio very kindly undertook, in May of this year, to secure further material, making for this purpose a considerable and somewhat arduous journey. On arriving at the locality above mentioned, he again found the desired species. Yet, although it was then more than a month earlier than when the plant was first observed, the flowers had already fallen and the fruit set. However, the more copious material now secured, corresponding in all points with the original specimen, leaves no doubt in the minds of the writers that this is a distinct species. It is distinguished from *V. dentatum* L. (which it most resembles in foliage) and from *V. molle* Michx., by its longer and much more compressed fruit and seed. The fruit is, in fact, very like that of *V. pubescens* Pursh. From the last named species, however, the present plant differs very decidedly in foliage, having, as may be seen from the accompanying plate, much more orbicular, deeply cordate, and much longer-petioled leaves, which are also of larger size than in any of the related species. The toothing of the leaves is somewhat different also from any of the species mentioned, the teeth here spreading in an even more radial manner than in *V. dentatum*.

Few states have received more botanical attention of late than Missouri, many portions of it having been carefully explored by Messrs. Bush, Eggert, Letterman, Blankinship, and others. This naturally argues that the present plant, which has not, to our knowledge, been



DEANE and ROBINSON on a new VIBURNUM.

secured before, must be a very rare and local shrub. Certainly the exact limits of its distribution will be a matter for interesting investigation. The species, so far as now known from fruiting specimens, may be characterized as follows:

Viburnum Demetrionis, n. sp.—A bushy shrub, about 12 feet high: stems 5 to 20, erect, terete, glabrous, becoming ½ to 1½ inches in diameter, at first bright green, soon ashy gray, and at length brownish or grayish black, and in age much roughened with lenticels; bark, on stems two years old, exfoliating in brownish sheets: bud-scales ovate, acutish, ciliolate, sub-carinate: leaves suborbicular, or broadly ovate, cordate with narrow sinus and broad rounded basal lobes, short acuminate, radially and sub-acutely dentate, bright green quite glabrous and sulcate-nerved above, somewhat paler green and soft-pubescent beneath; the larger ones 3½ to 5½ inches long, 3 to 3¾ inches broad: petioles furrowed above, glabrate, ¾ to 1½ inches long: stipules filiform, 2 to 3 lines in length: umbelliform corymbs terminal on the branches, pedunculate, 2 to 3½ inches in diameter, glandular-puberulent; the primary rays mostly about 7, rarely as few as 4: calyx (persisting on young fruit) with 5 lance-oblong obtusish hispid-ciliate teeth: fruit not very fleshy, oblong in outline, rounded at both ends, 5 lines long, half as broad, much compressed, and in dried state concavo-convex, the convex surface having deep intramarginal grooves: putamen of essentially the same shape.—Collected July, 1894, and May 29, 1896, by C. H. Demetrio, near "Big Cave," bluffs of Cole Camp creek, Benton county, Mo.

Mr. Demetrio reports that on his second visit to the above locality he found no less than 20 shrubs of this species growing within a radius of a quarter of a mile. He also found, a little to the north of the "Big Cave," a second species of Viburnum, which was growing so near the edge of the creek that some of the branches were immersed. This species proved to be *V. pubescens* Pursh in all essential regards, but it differs from any specimens, accessible to the writers, in having petioles 4 to 6 or in some cases even 10 lines long, approaching in this respect *V. Demetrionis*. It is, however, very different from that species in the size, contour, and dentation of the leaves, and its unusually long petioles may well have been due to its exceptional habitat.

Types of *V. Demetrionis* will be deposited in the Gray Herbarium, and the herbaria of the Kew Gardens, Arnold Arboretum and Missouri Botanical Garden, as well as the private collection of Mr. Deane.—W. DEANE and B. L. ROBINSON, *Cambridge, Mass.*

A NEW GENUS OF STERCULIACEÆ, AND SOME OTHER NOTEWORTHY PLANTS.

Nephropetalum, n. gen. of *Sterculiaceæ*.—Calyx deeply 5-parted; segments ovate. Petals 5, unguiculate, slightly adnate at base to the stamineal cup, free at the apex; blade small, reniform with a deep sinus at the attachment of the claw, concave, neither appendaged nor glandular. Stamens 5, united into a short cup; anthers 3-locular, sessile or nearly so, extrorse; cells parallel and longitudinally dehiscent. Staminodes 5, alternate with the stamens and opposite the sepals, rounded and cucullate at the summit. Ovary sessile, globose, 5-celled; cells 2-ovuled; ovules superposed on axial placentæ; style short, terete; stigma capitate. Young fruit globose, covered with very numerous pubescent processes; seeds by abortion solitary in the cells. —Stellate-tomentulose unarmed shrub with simple alternate ovate dentate petiolate leaves and small flowers in short axillary cymes. Most nearly related to *Ayenia* and *Buettneria*, and differing from the former in its free reniform petals and sessile ovary; from the latter in the entire absence of the appendage of the petals as well as in a very different habit. The origin and application of the generic name is apparent from the description.

N. Pringlei, n. sp.—Stem terete and nearly glabrate: leaves ovate, cordate with a narrow sinus, acuminate to an obtusish apex, crenate-dentate, palmately 7-nerved from the base, finely stellate-pubescent above, paler and tomentulose beneath, 3½ to 5 inches in length, 1½ to 3 inches broad: petioles canescent-tomentulose, 1½ inches long: stipules setaceous, deciduous, nearly 2 lines long: axillary umbelliform cymes 2 or 3-flowered, about an inch in length; the peduncles about equaling the pedicels: greenish flowers only a line in diameter.—Collected by C. G. Pringle, at Hidalgo, Texas, August 6, 1888 (no. 2272).

CORDYLANTHUS PILOSUS Gray, var. **trifidus**, n. var.—Pubescence duplex, consisting of a short close glandular puberulence and a loose spreading villosity: leaves broader than in the type, oblong rather than linear, distinctly 3-nerved, mostly 3-cleft below the middle: bracts also trifid; segments linear, entire, obtuse, somewhat dilated at the ends; the lateral spreading.—Collected by J. W. Congdon, on Chowchilla creek, Mariposa county, California, August 9, 1895 (no. 81).

AN INTRODUCED OROBANCHE, NEW TO AMERICA.—In July, 1895, Mr. J. A. Morton of Wingham, Ontario, collected on a lawn at that

place an orobanchaceous parasite, not referable to any species characterized in American floras. He accordingly forwarded specimens of the plant to the Gray Herbarium for identification, and it has proved to be *Orobanche purpurea* Jacq. Enum. Stirp. Vindob. 108: 252 (*O. cærulea* Vill. Hist. Pl. Dauph. 2: 406; *Phelipæa cærulea* C. A. Mey. Enum. Cauc. 104), a species of wide distribution in Europe and Asia. There is no doubt that it was introduced in its Canadian occurrence, and probably with grass seed. Mr. Morton notes the fact that it was found growing "among *Achillea Millefolium*." This fact, of course, adds further proof of the identity of the American and European plants, since also in the Old World this species is regularly parasitic upon *Achillea Millefolium*.

A hasty search through recent American botanical literature has failed to show any reference to the presence of *Orobanche purpurea* Jacq. Reports of other localities may be awaited with interest. A very curious parasite, which attacks chiefly, if not exclusively, a common and noxious weed, is far from being the most undesirable sort of immigrant. The genus *Orobanche* is, of course, most nearly related to our American genus *Aphyllon*, so closely in fact that the two are united by some European authorities. The former, however, is in general readily distinguished by its 4-lobed calyx, the calyx of *Aphyllon* being 5-cleft. *Orobanche purpurea* Jacq. has the habit of *Aphyllon Ludovicianum* Gray. The only other Orobanche that has been introduced into the American flora is *O. minor* L., a variable species, which, however, has flowers ebracteolate, while in *O. purpurea* the flowers are subtended not only by conspicuous single bracts but also in each case by a pair of lance-linear attenuate bractlets. The whole plant is very glandular pubescent. Although a number of individuals were found, Mr. Morton regards the species as of very recent introduction in his locality.

ELYTRARIA VIRGATA Michx., var. **angustifolia** Fernald, n. var.—Leaves linear or narrowly oblanceolate, 3 to 4 inches long, barely ⅓ inch wide: scape more slender and bracts of the scape shorter and more appressed than in the type, from which it does not otherwise differ.—An extreme form, hardly worthy of specific rank, collected in thin calcareous soil near Biscayne Bay, Fla., by A. H. Curtiss, July 23, 1895 (no. 5494).

Hemizonia Congdonii, n. sp.—Low annual or perhaps biennial, much branched from the base, covered especially below with a copious loose lanate pubescence: root slender-fusiform, somewhat branched:

woolly stems white striate-angulate, lucid, leafy: lower leaves pinniatfid, 2 inches or more in length, not rigid nor pungent tipped, 1-nerved, with about 6 pairs of unequal dentate segments, these obtusish or acute, diminishing in size toward the winged clasping petiole; middle and upper leaves inch or less in length, rigidulous, pinnately 3 to 7-toothed with spinulose-tipped pungent teeth, soft-pubescent on both sides and somewhat revolute on the margins: heads terminal or subterminal on the branches, only moderately aggregated, including the spreading bracts 6 to 8 lines long; the bracts green except at the pungent tip, entire or rarely 3-toothed, with midrib prominent beneath and considerably thickened toward the base: ray-flowers including the achenes only 2½ lines long, ligules 15 to 18, yellow, 3-toothed at the apex; the tube very glandular-pubescent; the pappus of the disk-flowers 3 erect narrow awns, nearly equaling the yellow corolla: chaff 2 lines long, scarious-margined and with thickened somewhat recurved tips.—Collected by Mr. J. W. Congdon, at Salinos, Monterey county, California, May 26, 1886 (no. 151). Most nearly related to *H. Parryi* Greene, but of lower stature, and with very different woolly pubescence, more divided foliage, and shorter ray-flowers.—B. L. ROBINSON and J. M. GREENMAN, *Harvard University*.

EDITORIAL.

DURING THE PRESENT MONTH there are meeting in Buffalo three botanical organizations of national scope: the Botanical Club of the A. A. A. S., the Botanical Section of the A. A. A. S., and the Botanical Society of America. Each organization has its own peculiar field, and has been a natural outgrowth from the remarkable botanical activity of the last few years. The question has been raised frequently whether this may not be an unnecessary multiplication of botanical organizations, and whether they may not overlap and interfere with each other. An examination of the original purpose of each makes it evident that no interference is contemplated.

THE BOTANICAL CLUB of the A. A. A. S. was organized when the botany of the Association was but a part of the Biological Section, and its double purpose was to bring the botanists together in a meeting of their own, and to provide a means for the informal presentation of botanical matters of interest and importance, but not adapted to formal presentation. There was no qualification excepting membership in the American Association, even those merely interested in botany being invited to enroll as members. It thus became and continues to be a very general botanical conference, with just organization enough to keep it in existence, and no publication. It is the best organization for the cultivation of a general botanical acquaintance, and the only botanical organization not strictly professional. It was not intended as an overflow from the Biological Section of the Association, except so far as the section was burdened by botanical material not properly belonging to it.

THE BOTANICAL SECTION of the A. A. A. S. was next established, when the botanical papers of the Biological Section justified a separate section. The papers of this organization are intended to be formal and professional, and are published by abstract in the widely circulated Proceedings of the Association, but the only limit to membership is the fee of the general Association. That botanists have repeatedly mistaken the purpose of this organization and have presented loose and rambling talks rather than formal and compact papers is not due

to any fault in the design of the organization. However, while the papers are intended to be professional, the audience is miscellaneous, and the subjects selected or their treatment takes cognizance of this fact. It is the place where investigators seek to present their results to the general scientific public, and a semi-popular style is demanded.

THE BOTANICAL SOCIETY OF AMERICA, the most recent of these organizations, is purely professional, both as to membership and audience, and the papers which naturally belong to it are not adapted to either of the other organizations, for they are technical in subject matter and style, and are all prepared for publication in full.

IT WOULD SEEM, from the above presentation, that there is abundant reason for the continued existence of all these organizations, and that they furnish the natural channels of communication for every grade of botanical work, from the briefly stated observations of the amateur to the most elaborate researches of the professional. The first organization has in view the gathering up of miscellaneous observations; the second regards the interest of the public in the results of investigations; the third is concerned solely with the progress of botanical science.

WE HAVE ALREADY alluded to the neglect of foreign literature by some German botanists, as illustrated by the paper of Dr. Correns on the physiology of tendrils.[1] Professor MacDougal called attention to Correns' culpable oversight in a recent note in the *Botanisches Centralblatt*.[2] Correns' reply in the same journal[3] makes the rather curious plea in extenuation, "dass die BOTANICAL GAZETTE in der jene Angaben publicirt wurden, in Tübingen nicht existirt." What would be thought of an American student who excused himself for not knowing of Correns' work by saying that the *Botanische Zeitung* was not to be found in his college library? While the two cases are not precisely parallel they are sufficiently so to show the invalidity of Dr. Correns' plea. And what bearing has Correns' assertion that the first experiment by which he recognized the heat reaction was performed a year before the publication of MacDougal's paper? It would have been much better for Dr. Correns not to plead "extenuating circumstances," but to content himself with a frank acknowledgment of his oversight. We hope the incident will awaken our German friends to the need of consulting at least the index to American botanical literature.

[1] BOT. GAZ. **21**: 248, 398, 304. 1896.

[2] **66**: 145. 1896. [3] **66**: 290. 1896.

CURRENT LITERATURE.

BOOK REVIEWS.

Warming's plant geography.

THE GEOGRAPHICAL DISTRIBUTION of plants has received much attention for many years, but the earlier observers could do little more than accumulate facts and outline general zones. With the development of plant physiology it became possible to organize these facts upon a scientific basis, and this organization introduces us into the great modern field of ecology, of which geographical distribution is a conspicuous part. Many recent contributions to this region of ecology are scattered through botanical literature, and the time has come for the summing up of results in some general work. Such a work has been prepared by Dr. Warming, and the German translation by Dr. Knoblauch[1] is now before us. It is impossible to give a compact review of such a work, as it is a compendium of important information; and little more can be attempted than to present a brief outline. It is to be hoped that the promised English translation will put the book promptly into the hands of English students. In the introduction the prominent terms are defined. Floristic plant-geography deals with lists, districts, limits, and causes; ecologic plant-geography, the subject of the book, considers adaptations, sociology, and physiognomy. "Life-forms" (epharmony) and "plant-societies" (Pflanzenvereine) are defined, the latter referring to those plant associations which take possession of certain conditions.

The second section discusses the ecological factors and their effects under the following titles: atmosphere, light, heat, atmospheric moisture and precipitation (water obtained from air and soil is emphasized as being the chief ecological factor), atmospheric movements, nature of the nutrient soil, the structure of the soil, the air in the soil, the water in the soil, the heat of the soil, the depth of the soil, the nutriment in the soil, the kinds of soils, chemical *vs.* physical properties of the soil (the author regards the physical properties as most important, as they control the water supply, which is the most important factor), effects of inanimate coverings on vegetation (snow and

[1] WARMING, DR. EUGEN.—Lehrbuch der ökologischen Pflanzengeographie; eine Einführing in die Kenntniss der Pflanzenvereine. Deutsche vom Verfasser genehmigte, durchgesehene und vermehrte Ausgabe von Dr. Emil Knoblauch. 8vo. Berlin: Gebrüder Borntraeger. 1896. *M.* 7.

fallen leaves), effects of living plant coverings on the soil, activity of animals and plants in the soil, orographic factors (height, steepness, etc.).

The third section considers life-relations and plant-societies under the following subjects: life-relationship of living beings, encroachment of man, life-relationship with animals, life-relationship of plants with each other (parasitism, helotism, mutualism, epiphytes, saprophytes, and lianas), commensalism (plant-societies), classes of societies (amplified in the succeeding chapters).

In section four the hydrophyte societies are considered, the ecological factor being air, light, heat, food-stuffs, specific weight, color, and movements; the structural adaptations noted being in roots, water-conducting vessels, mechanical tissues, air-cavities, epidermis, slime, etc. The different classes of hydrophilous societies are grouped as follows: free-floating or swimming; fixed to the soil, with submerged or floating leaves; and swamp forms. Under the first heading there are four categories, the plankton, glacial plant-unions (ice and snow), saprophilous flagellate unions, and hydrocharite unions (littoral fresh-water free plants). Under the second heading (fixed to soil, with submerged or floating leaves) are plants fixed to stones (nereid-unions), and those fixed to loose soil (sea-grass vegetation, fresh-water vegetation, and schizophyte unions. Under the third heading (swamp plant-societies) the subdivision is into salt water (mangrove vegetation) and fresh water (reed-swamps, swampy moors, sphagnum moors, sphagnum tundras, swampy thickets and woods). Each of these fourteen categories is fully discussed, all the known factors in each situation being considered.

Section five is devoted to xerophyte societies, which involves a full discussion of the adaptations for regulating transpiration and for collecting and preserving water. Under the regulation of transpiration the titles are periodic surface reduction, movements for regulating light, constant profile position (compass plants, etc.), leaves and shoots with reduced surface, covering organs, anatomical structures reducing transpiration, etc. The classification of xerophilous societies is as follows: rock vegetation (subglacial and temperate regions, tropical and dry rock vegetation), subglacial vegetation on loose soil (rocky fields, moss heaths, lichen heaths), dwarf shrub heaths (chiefly ericaceous), sand vegetation (beaches, dunes, sandy fields, etc.), tropical deserts, xerophilous grass vegetation (steppes and prairies, savannas), rocky heaths, xerophilous thickets (in cold and temperate regions, alpine thickets, tropical thorn, palm, fern, bamboo thickets), and xerophilous woods (evergreen conifers, deciduous conifers, xerophilous foliage woods, leafless woods).

Section six considers halophyte societies, the structural adaptations being very marked and often readily modified by removal from halophytic conditions. Naturally halophytes include both xerophytes and hydrophytes, and are grouped as follows: tropical swampy beach vegetation, salt marshes with

herbaceous plants (mostly Scirpus-like), rock societies, herb and shrub vegetation in salty sand and gravel, tropical sand-beach woods, leafless halophyte woods in sand, herb and shrub vegetation in clay soil (lagoon thickets, salt steppes), salt deserts, and beach meadows.

The mesophyte societies form the subject of section seven. The general condition is freedom from extremes. The vegetation is rich and dense, and there is great richness in leaf forms. This is the common vegetation of temperate regions and includes the numberless new societies of weeds and culture plants introduced by man. The grouping of mesophyte societies is into grass and herb societies and societies of woody plants. Under the former are included arctic or alpine grass or herb carpets, meadows, pastures on cultivated lands; under the latter, thickets, deciduous woods in temperate zones, and evergreen foliage woods (subtropical, antarctic, tropical rain woods, palm woods, bamboo woods, fern woods).

The last section discusses the struggle between plant societies. After general introductory remarks concerning the nature of the struggle, the facts of overproduction, the easy derangement of the organic equilibrium, etc., the main topics discussed are the production of new soils and their occupation, changes in vegetation induced by slow changes in soil, changes in vegetation without changes in climate or soil, the weapons for the struggle, rare species, the origin of species. We have space for fuller statement of but two of these topics. The general characteristics of vegetation occupying new soil are given as follows: The first vegetation is sparse and open; the number of species is small at first, then larger when the physiognomy is diverse, then comes an equilibrium and fewer species; annuals and biennals are common at first, but afterwards subordinated to perennials; the first species are those whose seeds are carried by winds and birds; light-trees appear before shade-trees; there is a gradual transition to former conditions, and thus there may be primal, transitional and final plant societies. In reference to the origin of species, the author believes that plants possess an innate power of adapting themselves directly to new conditions, a view which he supports by numerous illustrations of direct response of plants to changed conditions. This he regards as one of the greatest factors in the evolution of plants. Others are acquired variability, depending upon descent and not environment; natural selection; crossing of species; and correlation between the parts of a plant, a change in one part affecting the others.

The book certainly meets the demands of a "Lehrbuch" admirably, being comprehensive and yet full enough of details. Its arrangement is to be highly commended, as the numerous subdivisions enable one to find any special topic at a moment's notice. Very few references are made to American plant-societies, chiefly because they have not been investigated sufficiently.—J. M. C.

Text-book of general botany.

ANOTHER work on general botany, of moderate size, and of a grade for use in colleges, has been provided for English students by the translation of Westermaier's recent volume. The translation has been made by Dr. Albert Schneider,[2] and with the exception of occasional aberrations in the use of *shall* and *will*, and some remnants of Teutonic phrases, it is acceptably done.

There are two reasons why this work is likely to meet with favor from a number of teachers. In the first place it intimately combines physiology with morphology and at every step inquires what use the particular cell, tissue, or organ serves. And then it comes from a new source, being dominated by the views of Schwendener and Nägeli, while our text-books heretofore for the most part have represented the views of Sachs and his followers.

The work is of a suitable size for text-book use, but is not to be put into the hands of novices in botany. For students who have passed the rudiments of the science, and who know something of chemistry and physics, and of the current theories of descent, it will prove serviceable, and, moreover, will be more than ordinarily suggestive and inspiring.

The work is not large, but inclines to be compendious, and this has necessarily led to condensing weighty matters into such brief compass that many statements will prove barely intelligible to the ordinary student unless expounded by a teacher.

While the work has many good qualities, there are some features of it that will surely meet with disapproval from well-informed instructors. The author has failed many times to present the latest and most approved views upon disputed or recently settled topics, especially when such views are in opposition to those of the school to which the author belongs. An instance of this is the presentation of Nägeli's theory of the growth of starch grains and cell wall by intussusception to the extent of several pages, while there is barely mention of the fact that there are later and more acceptable theories, and no attempt to outline them or name the investigators. We can, of course, afford to be a little charitable when the author insists upon his own imperfect views regarding the rise of sap in plants, and we have a curiosity to know just to whom or what he refers when he says that "in regard to this question many authors hold erroneous opinions;" but he does not enlighten us.

The trouble which the author takes to show his opposition to the prevailing views in evolution seem strange in such a work, and does not heighten our appreciation of it. There are many out of date points of view and a corre-

[2] WESTERMAIER, MAX.—A compendium of general botany. Translated by Albert Schneider. 8vo. pp. 299. figs. 171. New York: John Wiley and Sons. 1896. $2.00.

spondingly antiquated terminology maintained in the work, *e. g.*, as to the process of photosyntax in the chlorophyll grain, which is called assimilation, although genuine assimilation is also mentioned. Thus we get this highly ambiguous sentence: "The cotyledons begin the function of assimilation as soon as the reserve food is assimilated." Another instance of a similar nature is in regard to reproduction. Although the author states that "the entire phanerogamic plant with its flowers represents the asexual generation," he constantly speaks of male and female flowers, and of the gynœcium and androœcium as male and female organs.

There are good things in the book, and we are grateful to the translator for making available for class use a work in which the theories of Schwendener, Nägeli, Haberlandt and their followers are prominent; but it will not do to accept it unthinkingly, even with the translator's footnote corrections. The order of the subjects is as follows: the cell, tissues and simple organs; organs and systems of organs, reproduction, general chemistry and physics of plant life, taxonomy.—J. C. A.

The hardy bamboos.

MR. A. B. MITFORD, author of "Tales of Old Japan," has just given another result of his former residence in Japan in a book entitled "The Bamboo Garden."[3] The book does not profess to be technically scientific, but it is none the less interesting to botanists, containing much information concerning a large and important group of plants. It deals with the hardy bamboos in cultivation in England, thirty-eight of them being from China and Japan, one (*Arundinaria macrosperma*) from the United States, five from the Himalayas, and three whose nativity is uncertain. The Himalaya region is looked upon as likely to be the most productive of new forms, those of China and Japan having been long known and cultivated. The interesting facts concerning their inflorescence are pointed out, especially the fact that it occurs at long intervals of time, and then in a wonderfully simultaneous way over large areas, and results in the death of the plants. The older travelers, observing this phenomenon, have put upon record the often quoted statement that the plants after inflorescence die throughout, and that new growths come from the seed. They speak of great forests of bamboos disappearing in a single season, a serious calamity to communities so very dependent upon it as are the orientals of Eastern Asia. While this wholesale destruction at long intervals does actually occur, new growths spring very rapidly from the widespreading rootstocks. The interval between times of inflorescence was formerly stated definitely as thirty years; but, though infrequent, it varies widely,

[3] FREEMAN-MITFORD, A.B.—The bamboo garden. 8vo. pp. xii + 224, illustrated by Alfred Parsons. London and New York: The Macmillan Co., 1896. $3.00.

dependent upon climatic causes. What has been called the "suicidal mystery of the flower" is graphically stated as follows: "When the given moment has come round, every plant of the same species, whether old or young, over a vast region will put forth its flowers at one and the same moment, and, having seeded, for a time the plant disappears." A curious instance is given of this phenomenon observed under cultivation. In 1867 or 1868 *Arundinaria Japonica* began to bloom in Paris; "at the same moment" blossoms were noted on the plants at Marseilles; and even those in the government gardens at Algiers "flowered in concert with their European brethren; and not only did the whole of the canes, old as well as young, bear flowers together, but the very shoots (three to four inches high) as they showed above the soil, were transformed into flowering stems." In this case, however, the plants were not killed, but very much weakened; for a long time "remaining paralyzed." Mr. Mitford has observed that only those species are hardy in England whose leaves show "tessellated" venation, that is, "in chequers, crossing one another like the threads of a spider's web or the meshes of a net." The tender species observed all have leaves with the ordinary "striated" venation. Mr. Mitford has also observed this same tessellation in the leaves of the only hardy palm of England (*Chamærops excelsa*), and its absence in the tender palms. Mr. Thiselton-Dyer is quoted as remarking that "there must be something important behind a character like this."

The book is handsomely gotten up in white buckram and gilt, on thick paper with deckel edges. The full-page illustrations by Alfred Parsons are charming.—J. M. C.

The Bonn text-book.

WHEN four of the botanical staff of the University of Bonn combined to write the text-book which, fifteen months after the first, appeared in a second edition,[4] they owed it to their readers to choose a more distinctive title than *Lehrbuch der Botanik*. One cannot cite it now in any decently brief way, but must perforce reel off the list of author's names like a catalogue! For this is a book that one needs to name to students, and that often. No text-book at all comparable with it has been produced in recent years, and unless we much mistake, it is destined to be of somewhat the same value to the present generation as Sachs' classical *Lehrbuch* was to the last. Its excellence carried it through four German and two English editions, besides others in other languages, while it directly inspired and formed the model for various texts by different authors. Much of the excellence of the Bonn

[4] STRASBURGER, NOLL, SCHENCK, and SCHIMPER:—Lehrbuch der Botanik für Hochschullen. Zweite umgearbeitete Auflage. 8vo. pp. vi+556. figs. 594, in part colored. Jena: Gustav Fischer. 1895. *M.* 7.50 unbound; *M.* 8.50 bound.

text-book is due to the division of labor made possible by having four collaborators, each a specialist in the section he treats.

Was it pure accident that exactly one-fourth of the pages are by Strasburger, on morphology, one-fourth by Noll, on physiology, while in the remaining half, the cryptogams, by Schenck, yield a little to the phanerogams, by Schimper? There seems something too much of exactness here for pure accident, particularly as one would hardly expect such a division of space from the nature of the subjects.

It is difficult, where all is so good, to point out the best; yet every reader will concede the palm to the first half of the book. External morphology is cut rather short by Professor Strasburger, and we are so charmed by his treatment of the internal morphology that we are less ready to forgive him the abbreviation. The presentation of the physiology is particularly clear and effective. But the enumeration of the characters of each order, and even of each family among the phanerogams, seems to us barren and unfruitful. Why can we not have a treatment of special morphology which shall be more thoroughly comparative? There is need to organize the facts known so that they shall form for the student a body of symmetric truth, rather than remain disconnected members, related indeed, but scattered as it were in a valley of dry bones. Some attempt at this indeed is made by both Schenck and Schimper, and with much greater success by the former. Schimper seems less able to free himself from the overpowering precedents in the treatment of phanerogams, so that one finds less that is fresh or suggestive here than in any other part of the book.

Yet it is all good after its kind; well put, well printed, excellently illustrated. The colored figures are rather for show than of value, though they are quite truthful in color. We hope soon to welcome an English translation of this excellent book.—C. R. B.

MINOR NOTICES.

MR. B. T. GALLOWAY has prepared a brief paper upon "Frosts and freezes as affecting cultivated plants," in which he has brought together some of the more important facts relating to frosts and freezes as affecting the farmer, gardener, and fruit grower. The paper appears in the Yearbook of the Department of Agriculture for 1895, or may be obtained as a separate. —J. M. C.

MR. A. S. HITCHCOCK, in the last bulletin (no. 57) from the Kansas Experiment Station, which is the third contribution upon the subject of Kansas weeds, introduces some useful features in presentation. Instead of the customary bare list, with perhaps a few notes, the list is a descriptive one, with easy artificial keys; numerous plates give typical leaves, to aid in iden-

tification; and the distribution by counties of almost all the species is shown upon 172 reduced maps.—J. M. C.

THE FIRST REPORT on the flora of Wyoming by the botanist of the Experiment station, Mr. Aven Nelson, has just appeared (May) as Bulletin no. 28. The list of species, with full notes, contains 1118 spermatophytes, all of which are represented in the herbarium of the station. A very convenient feature of the report is that it also contains lists of plants reported for the state but not represented in the herbarium. Fourteen new forms are described, eleven of them as varieties, and three as species (*Aquilegia Laramiensis*, *Potentilla pinnatisecta*, and *Hymenopappus ligulæflorus*).—J. M. C.

ACCORDING TO Mr. Herbert J. Webber, who has studied the pineapple industry in the United States, this tropical fruit, indigenous to South America, is being so extensively cultivated in southern Florida as to be worthy of consideration. The sources of large supply for the United States have been and still are the West Indies and Bahamas, but with about 2500 acres already in cultivation in Florida and the possibility of large extension, increased demand for the fruit may be met by home supply. Mr. Webber presents a full report of his studies in the Yearbook of the Department of Agriculture for 1895.—J. M. C.

THE TUMBLING MUSTARD (*Sisymbrium altissimum*) has begun to attract the attention of those interested in agriculture. Apparently a native of the Mediterranean region, it has spread throughout Europe, northern Africa, and western Asia, as a troublesome weed in cultivated fields and meadows. During the past five years it has made extensive inroads in the Canadian northwest provinces, and now it is reported from nine different localities in the United States, ranging across the continent, and as far south as Missouri. Its method of seed dispersion is indicated by its popular name. The Department of Agriculture has sounded a note of warning, and has given all necessary information, in Circular no. 7, issued from the Division of Botany, and prepared by Mr. Lyster H. Dewey.—J. M. C.

IT MUST BE that such books have a distinct place to fill, or they could not run to third editions as has Mathews' *Familiar Flowers*.[5] This one has its striking merit in its illustrations, most of which are accurate and altogether admirable, though the author, who is likewise the artist, sometimes fails to catch the texture of his leaves. But the illustrations allow ready identification of the commoner attractive plants of the northeastern states. The chatty

[5] MATHEWS, F. SCHUYLER:—Familiar flowers of field and garden, described and and illustrated, with over 200 drawings by the author, and a systematical index and floral calendar. Third edition, 12 mo. pp. viii + 308. New York: D. Appleton & Co. 1896.

notes which accompany each figure are interesting, but unfortunately sometimes "popularize" facts at the expense of accuracy. It needs to be insisted upon that simplicity of statement need not involve any inaccuracy. Why, for example, should the author mislead his readers by comparing the chicory head with a single flower in this wise: "Not only these straps, but the center of the flower (the stamens and styles) looks very much like the dandelion." And of the everlasting (*Gnaphalium*) he writes: " . . . the little white flowers are so much like miniature pond lilies under the microscope that the resemblance is amusing," For the readers, however, these slips will not be disquieting, and are only worth mention because they mar an otherwise good book.—C. R. B.

ONE OF THE most interesting contributions from the National Herbarium is that by Mr. P. A. Rydberg upon the flora of the Black Hills of South Dakota.[6] The region is often called an intermediate one, because the floras both east and west of it have received more attention. The report, therefore, deals with one of the regions most in need of investigation. In his prefatory discussion Mr. Rydberg deals with such topics as geography, geology, altitudes, precipitation and temperature, and floral districts. Under the last topic he considers five districts differing in topographical and climatic conditions, and hence in vegetation. They are the foothills, Minnekahta plains, Harney mountain range, limestone district, and northern hills. It is interesting to note that the characteristic plants of the foothill region are grouped as follows: very hairy plants; plants with a glaucous foliage having a hard epidermis; plants with white, often shreddy, stems; plants in which the surface is reduced to a minimum; and plants with a deep-seated, enlarged root. The catalogue of species, which is full of valuable notes as to range and habit, contains about 700 spermatophytes and pteridophytes. One of the most interesting discoveries was that of true *Aquilegia brevistyla* in the United States, the plant from the Rocky mountains heretofore bearing that name having been proved to be quite a distinct species, which Mr. Rydberg has called *A. saximontana*. The plates consist of a good map of the region the two Aquilegias referred to, and *Poa pseudopratensis*, a new grass.—J. M. C.

NOTES FOR STUDENTS.

ROSENBERG has found[7] that in herbaceous perennials differences in the starch content exist in the course of the winter similar to those well known in trees through the very exhaustive researches of Fischer.—C. R. B.

[6] RYDBERG, P. A.—Flora of the Black Hills of South Dakota. Contributions from the U. S. National Herbarium **3**: 463–536. 1896. [No. 8.]

[7] Bot. Centralb. **66**: 337. 1896.

DANGEARD has described the life-history of a parasite of the nucleus of *Amœba*, and named it *Nucleophaga Amœbæ*. It is probably one of the lowest Chytridiaceæ, related to *Sphærita*, which is a recently discovered parasite on *Euglena*.[8]—C. R. B.

IN REVIEWING the species of *Asimina*, Mr. Geo. F. Nash recognizes (*Bull. Torr. Bot. Club* **23**: 234. 1896) seven species, one of which (*A. speciosa*) is described for the first time, having been confused heretofore with *A. grandiflora* Dunal, which becomes *A. obovata* (Willd.)—J. M. C.

DR. F. W. KLATT has just described (*Bull. Herb. Boiss.* **4**: 456–475 and 479, 480. 1896) the following new genera of Compositæ, all African except the last, which is Cuban: *Symphipappus* (Inuloideæ), *Distegia* (Helianthoideæ), *Dolosanthus* (Mutisiaceæ), *Monactinocephalus* (Mutisiaceæ), and *Lepidesmia* (Eupatoriaceæ?). Each genus is illustrated with a plate.—J. M. C.

WINOGRADSKY has communicated to the Paris Academy of Sciences[9] the results of M. V. Fribes' researches in his laboratory at St. Petersburgh upon the maceration of flax for the isolation of the fibers. The rotting is due to an obligate anaerobic bacillus, which acts not as a cellulose ferment but as a pectin ferment. It dissolves the middle lamella of the cortical parenchyma which consists of calcium pectinate, and thus isolates the fibers.—C. R. B.

MR. P. A. RYDBERG has begun a series of notes on *Potentilla* (*Bull. Torr. Bot. Club* **23**: 244. 1896), in which his views as to the limitation of species differ widely from those of Dr. Watson (*Proc. Amer. Acad.* **8**: 549–573), and agree closely with those of Dr. Christian Lehmann, of Hamburg, whose "Revisio Potentillarum" (1856) serves as a basis for the present work. As the genus is one of the most perplexing of our flora it is to be hoped that Mr. Rydberg will be successful in this attempt to disentangle the species.—J. M. C.

M. J. BRIQUET announces (*Bull. Herb. Boiss.* **4**: 354. 1896) the discovery of a hybrid between *Bupleurum ranunculoides* and *B. longifolium*, two species very distinct morphologically and topographically. The discovery is interesting, not merely on account of the distinctness of the parent species, but also because of the extreme rarity of reported hybrids among the Umbelliferæ. The hybrid, named *B. Guineti*, seems well established, is distinctly intermediate in its characters, and exhibits a wide range of variation.—J M. C.

AMONG THE NEW Verbenaceæ recently described by J. Briquet (*Bull. Herb. Boiss.* **4**: 336. 1896), *Xeroplana* is a new genus from South Africa; *Lippia Pringlei* is a new species from Guadalajura, Mexico (*Pringle* 1733, dis-

[8] *Cf.* Bot. Centralb. **66**: 256. 1896.

[9] Compt. Rend. **121**: 742. 18 N 1895.

trib. of 1888); *Callicarpa Pringlei* is a new species from San Luis Potosi (*Pringle* 3094); *Vitex Hemsleyi* is a new species from near Oaxaca (*Jurgensen* 68), referred to by Hemsley in Biol. Centr.-Am. Bot. **2**: 540; *Citharexylum Jurgenseni* is a new species from near Oaxaca (*Jurgensen* 259); and the remaining nine species are mostly from northwestern South America.—J. M. C.

ABOUT A YEAR and a half ago Askenasy suggested that the vexed question of the ascent of water in plants was explicable by the force of imbibition of the cell-walls of the leaves and the cohesion of the water columns in the ducts.[10] He has devised an ingenious apparatus to illustrate the physical principles involved, which imitates fairly well the conditions in the plant. The fault common to the apparatus used by Jamin, Naegeli, and Strasburger is that the conducting portion consisted of porous material and was not essentially different from the evaporating and lifting portion. Askenasy's apparatus consists of a glass tube 90^{cm} long and $2.2–3.5^{cm}$ in diameter, ending in a small funnel which is plugged with gypsum or even has the gypsum spread over its whole inner surface. The gypsum corresponds to the membranes of the leaf, the tube to the wood vessels in which the water ascends. With certain precautions the tube is filled with water, its open end immersed in mercury, and fastened upright. In one experiment in 33 hours the mercury rose to 82^{cm}, and in another in 26 hours to 89^{cm}, *i. e.*, into contact with the gypsum. In the first its complete ascent was hindered by the formation of an air bubble. (*Cf.* Bot. Centralb. **66**: 379. 1896)—C. R. B.

DR. MAXWELL T. MASTERS has published from time to time the results of his researches among the Coniferæ. His most recent contribution deals with the genus *Cupressus*,[11] which he has reexamined with fuller material and assistance. The genus he regards as well-defined among its allies by the peltate expansion at the free end of the cone-scales, but the species are very difficult of limitation on account of the great inconstancy of the characters used, as well as the long cultivation of many of them. They are remarkably polymorphic, a certain well-known "stage of growth" in some species having given rise to the old genus *Retinospora*. The author regards *Chamæcyparis* as unworthy of generic rank, and is inclined to believe that the closely allied *Thuya* and *Libocedrus* might well be merged under *Cupressus*. His presentation of the alliances represents two divergent lines from *Cupressus*; one leading to *Juniperus*; the other, through the *Chamæcyparis* forms, leading to *Thuya*, *Libocedrus*, and *Fitzroya*. The varieties of foliage are discussed, but no physiological or phylogenetic significance suggested as explanatory of their

[10] Verh. nat. hist.-med. Ver. zu Heidelberg N. S. **5**: (1–23). 1895. *Cf.* Bot. Cent. **60**: 237. 1895.

[11] MASTERS, MAXWELL T.—A general view of the genus Cupressus. Jour. Linn. Soc. Bot. **31**: 312–363. 1895.

extreme anatomical diversity. The cone-scale, that fruitful organ for morphological discussion, shows distinctly its double nature in containing two distinct vascular systems, which are given off separately from the axis, the system of the seminiferous-scale portion having an inverse orientation of its elements. Fourteen species are recognized, five of which belong to the subgenus *Chamæcyparis*. The North American species are as follows: *C. Benthami*, of Central America, Mexico, and adjacent United States, and under which Greene's *C. Arizonica* appears as a variety; *C. macrocarpa*, of California, under which Watson's *C. Guadalupensis* appears as a variety; *C. Goveniana*, of California; *C. Macnabiana*, of California; *C. thurifera*, of Mexico; *C. thyoides* (*Chamæcyparis sphæroidea*, *Thuya sphæroidea*), of the Atlantic coast; *C. Nootkatensis* (*Cham. Nutkænsis*, *Thuya excelsa*), of the Pacific region from Oregon to Alaska; and *C. Lawsoniana* (*Cham. Lawsoniana*), of California and Oregon.—J. M. C.

MR. F. W. KEEBLE, during a brief stay in Ceylon in 1894, made a very considerable number of interesting observations, some of which he presents in a paper published in the Transactions of the Linnean Society of London, and more of which he promises to give in subsequent papers. In the present paper he sets down some of his observations on the Loranthaceæ native in Ceylon.[12] These green, semi-parasitic phanerogams have been attracting more than usual attention of late, as is shown by Van Tieghem's numerous publications concerning them, as well as others by less well known authors. Mr. Keeble's paper concerns itself first with the pollination of the flowers, which are large and conspicuous in many species, and deviate more or less from the regular type. To the observations of Wallace and others, that the tubular loranths are bird-pollinated, Keeble adds his own, giving greater precision to what was already known and contributing some new facts. Those flowers which depart from the type by developing a slit in the tubular corolla, and by placing the opened anthers in a row behind the style instead of in a ring around it, apparently derive a double advantage. The birds which frequent these flowers, being larger and less accurate in their movements than pollinating insects, are likely to rupture the delicate parts more or less, and do this even when the corolla is already split and the stamens are arranged in a row, though of course to a smaller and less damaging extent in such cases. Furthermore, their beaks, when these come into contact with the anthers on pushing into the flower, become dusted with pollen only upon the upper half, and deposit some of their pollen upon the protruding style of the next flower visited before pushing against its anthers. In those species whose otherwise tubular corolla is cleft, the stealing of nectar by birds which bite into the corolla-tube without cross-pollinating is materially less than in other species. A very considerable number of species have flowers which open only when

[12] Transactions Linnean Society of London, 2d Series, Botany **5**: [May]. 1896.

struck. The blows which are needed to open such mature flowers are ordinarily given by the birds which frequent them. Mr. Keeble suggests that this is an adaptation which is mutually advantageous: "The bird knows it is worth its while to 'tap a new barrel' as it were," for obviously there will be most nectar in such still unopened, and ence unvisited, flowers; and the pollen is protected from rain. This, since the majority of the species with exploding flowers either blossom during the rainy season or else grow where there is almost daily rain the year through, is a matter of considerable importance. Blossoming during the rains, even when not a matter of necessity, may be an advantage, since the seeds germinate most successfully, if not exclusively, in moist air.

As to the dissemination of seeds, Mr. Keeble disagrees somewhat with the generalizations of some authors on the subject,[13] to the effect that the seeds pass through the alimentary canal of birds and are dropped in their excrement unharmed upon the branches of trees. He finds that, of the large seeds at least, such few as are swallowed are decomposed, if not profitably digested, but that most of them are carefully expelled from the fleshy pulp before it is eaten, and if they adhere to the bird's beak are rubbed off upon any convenient object, a branch or even a telegraph wire. "On the single telegraph wire," at the Hill-Garden of Hakgala, "there are every year hundreds of seedlings of *Loranthus loniceroides*, all in early stages of germination." Furthermore, the large amount of tannin found in the coats of the seeds would make them unpalatable, and prove a useful protection against the seeds being swallowed.

In the tropical species of the Loranthaceæ, germination begins as soon as the ripe seeds have fallen where there is sufficient moisture, if not in the substratum, at least in the air. In *Loranthus loniceroides* the large seed sticks in a vertical position upon a branch or similar object, usually with the plumule pointing downwards because of the very adhesive *viscin* which is most abundant at this end. From the upper end the chlorophyll containing hypocotyl grows out, its enlarged apex or head pointing vertically upwards and carrying a drop of resin. During its subsequent growth, the hypocotyl curves over and finally, if it has attained sufficient length so to do, applies its head, now enlarged somewhat into a disc-shaped "sucker," vertically upon the support. The cells in the center of the sucker become papillate and penetrate the superficial cells of the host, while meantime the peripheral cells of the sucker have multiplied and grown, and thus furnish a broader and stronger attachment to the host. After such an attachment has been effected, the hypocotyl straightens, thus detaching the seed from the branch and carrying it up into the air. Much of the food has been transferred from the endosperm to the hypocotyl and may perhaps be temporarily stored, for the nourishment of

[13] "The Natural History of Plants," Kerner, trans. Oliver, 2: 205.

the haustorium, in the enlarged sucker. Then the cotyledons and the remainder of the endosperm are cast off and the plumule appears. This small structure develops minute leaves in pairs upon successive nodes separated by very short internodes, the leaves falling soon after formation. Only after the haustorium has penetrated the host does any development of branches take place; then, however, growth becomes very rapid and large leaves form. Mr. Keeble interprets the growth of a lateral aerial root from the sucker, a phenomenon which not infrequently occurs before the penetration of the haustorium into the host, especially on small or poorly nourished branches, as throwing light on the manner in which these plants became parasitic. "The seeds, originally sticky, often lodged on trees, and, as in many species of Ficus, these seeds, germinating, threw out roots which rapidly reached the ground, or the earth which collects in the forks of trees. To enable the plant to exist in this early non-parasitic stage, the base (free end) of the sucker came to function as a reserve food store. From this stage the natural semi-parasitism was reached by the ability of certain cells of the distal end of the hypocotyl to penetrate the host."

The curvature of the hypocotyl, above referred to, has long been known to be independent of gravitation (it is ageotropic) and has been attributed solely to the influence of light (it is negatively heliotropic, and hence bends toward the central shaded portion of the tree to reach the branch upon which the seed has fallen and stuck); but Keeble demonstrates, by germinating the seeds in the dark, that the hypocotyls of some species imitate tendrils, and hence may, often do, succeed in applying their enlarged heads to the surface of branches in this way. Owing to the resinous matter which covers them, the heads stick. In these species, the nutation may cause the head or sucker end of the hypocotyl to point temporarily directly towards the light, but it obviously supplements the negatively heliotropic curvature at other times and hence is advantageous to the seedling. Though the general surface of the hypocotyl is not sensitive to the contact of solid bodies, the growth of the head or sucker, and its close application and subsequent attachment to the branch, are to be attributed in part to irritation by such contact. Contact with lifeless or otherwise innutritious objects does not, however, induce such active and prolonged growth as is produced by contact with a suitable host. On the other hand, the growth of the haustorium from the head and toward the solid object seems to be induced by contact with any solid body. Keeble describes an experiment in which he applied a small cover-glass to the head of the hypocotyl of *L. loniceroides*, with the result that there was only slight enlargement of the head, which had not developed an effective sucker, though it remained fast by reason of the adhesive resin, whereas the haustorium had grown out to a distance of 2^{mm} beyond the margin of the disc, being deflected from its course by impenetrable glass. The cells which form the central part of the surface

of a sucker which is in contact with a host become papillate, and, by pressure and solvent action combined, penetrate the superficial cells of the host. When these have succeeded in penetrating, the sucker enlarges still more, and thus furnishes a strong brace for the haustorium, which must necessarily develop considerable pressure to penetrate into the deeper tissues of the host, although at the same time it may perhaps supplement this mechanical penetration by the softening or solvent action of any enzymes which it may be able to secrete. In these ways the behavior of the haustorium and the sucking-disc of the Loranthaceæ is not unlike that of the completely parasitic phanerogams. In an appendix, Mr. Keeble describes the forms of the fruits and seeds of some of the Cingalese Loranthaceæ. This interesting and suggestive paper is illustrated by several woodcuts and two large well-executed lithographic plates.—GEORGE J. PEIRCE.

OPEN LETTERS.

CAN RESEARCH WORK BE ACCOMPLISHED IN AMERICAN LABORATORIES?

To the Editors of the Botanical Gazette: — It has long been the custom of American botanists to make comparisons of the facilities for research afforded by our own laboratories and those of Europe, to the great disparagement of the former. In view of our rapid development in methods of elementary teaching, and the yearly establishment of a number of new chairs of botany, it may be well to inquire at this time into the particulars upon which our alleged inferiority is based, that we may remove the chief faults if inherent in our system of organization, or grow out of them as rapidly as possible.

The essential factors for original work are a group of living or prepared plants, a laboratory, the literature of the subject to which attention is directed, and a moderate amount of cerebral matter in possession of an enthusiastic determined person with thorough training and persistent botanical tendencies.

So far as plants are concerned, the American botanist has at his very door hundreds and thousands of species which furnish ample material for the solution of some of the more important problems, particularly those to be solved experimentally, a fact needing no discussion.

The chief dissatisfaction with our laboratory facilities arises from a narrow view of the fields open to research. No laboratory in the world is fitted for research in even a majority of the phases of the subject, and it is quite as easy to fix upon some problem which may not be worked out in a given laboratory, as it is to select those for which it is especially effective. This is especially true so far as apparatus is concerned.

It has come to be recognized in the laboratories in which research is most actively prosecuted, that costly and complicated pieces of fixed apparatus are by no means a requisite for the performance of valuable work, but that the proper appliances in each instance should be extemporized from a common stock of glass, wood, and hardware. In order to place a definite statement on record, the writer insists that even the laboratory with a yearly expense account of "thirty seven dollars" is not entirely debarred from research.

Perhaps the greatest difficulty which confronts the American worker is the lack of reference literature. There are, however, several extensive libraries in the country which are readily accessible, and with the exercise of

some patience the investigator may possess himself of the information concerning work previously accomplished upon his subject, in ample time for the publication of his results. In many instances he may own the literature at a very slight cost.

Most serious of all, however, are the subjective difficulties of the director of the laboratory, who to the above category, adds that of lack of time, etc., and constantly calls attention to the fact that our European colleagues do so little actual teaching and executive work that they are able to accomplish a large amount of investigation; a statement by no means confirmed by the personal experience of the writer in the more important laboratories of Germany and England. A dozen pages of this journal might be filled with titles of work accomplished with as limited facilities and under as great a stress of other duties as those which confront the American worker, and the writer confidently asserts that any American botanist may accomplish a certain amount of research if he is fully determined upon it, and that, too, without recourse to the "holidays and Sundays" in which a German zoologist completed a recently published work. It appears, therefore, that the greatest hindrances to research work lie, not in our material facilities or organization, but rather in the mental attitude of our would-be (?) investigators. In order to dispel any doubts remaining it might be well for the GAZETTE to publish a second laboratory number, which would also show our progress in that particular during the last decade.

In conclusion it is proper to state that by original work is not meant the collection of a number of random observations, but the acquisition of new facts, which added to those already known will suffice for the formulation of new laws, or the extension, or critical delimitation of existing generalizations

D. T. MACDOUGAL, *University of Minnesota.*

NEWS.

MR. J. C. WILLIS has been appointed director of the Royal Botanic Gardens of Ceylon.

AT THE MEETING of the Linnean Society of London on May 7th, Profes- D. H. Campbell was elected a foreign member.

PROFESSOR D. T. MACDOUGAL returned from Europe August 15, after a short period of study in Professor Vöchting's laboratory at Tübingen.

DR. J. C. ARTHUR left Bonn about August 15th, intending to spend a few days in England, and to reach his work at Purdue University, September 1st.

MR. W. L. BRAY, who has recently had charge of the botanical work at Lake Forest in the absence of Dr. Harper, has gone to Germany to spend a year in study.

THE OBSERVER (Portland, Conn.) has been greatly enlarged and improved. It is now one of the best periodicals for amateur naturalists which comes to our table.

PROFESSOR R. A. HARPER, of Lake Forest University, returned from Europe a short time since. He was the recipient of the doctorate from the University of Bonn during the last semester.

MR. W. J. V. OSTERHOUT has accepted the position of instructor in botany in the University of California. He recently returned from a year's study in Professor Strasburger's laboratory at Bonn.

DURING A RECENT visit of the king of Siam to the Botanic Garden at Buitenzorg the dignity of Commander of the Order of the White Elephant was conferred upon Dr. M. Treub, director of the gardens.

DURING THE SEMESTER just closed the workers in Professor Strasburger's research laboratory at the Botanic Institute, Bonn, included five Americans, two Germans, one Swede, one Pole, one Russian and one Englishman.

Mr. D. G. FAIRCHILD, after more than two years' study in European laboratories, has gone to Buitenzorg, Java, to carry on further researches. He has severed his connection with the United States Department of Agriculture.

DR. H. SCHENCK of Bonn, who was recently made professor extraordinary, has accepted the position of professor ordinary at the Polytechnicum at Darmstadt and director of the botanic garden, to succeed Professor Dippel, who retires from active work.

COULTER'S *Flora of Western Texas*, published among the contributions from the United States National Herbarium, and issued in three parts, has been republished and bound into a single volume. The original edition of the first part had been entirely exhausted.

DR. E. KOEHNE, of Friedenau bei Berlin, the well-known dendrologist and editor of the *Botanisches Jahresbericht*, has begun the issue of a "herbarium dendrologicum adumbrationibus illustratum," by the distribution of the first century. The generally poor representation of woody plants in herbaria ought to make this set of exsiccatæ particularly acceptable.

PROFESSOR DR. COMES, who has been for some years engaged in a study of tobacco, offers seeds of a very large number of garden varieties, forms and their hybrids in exchange. He especially requests those who have any uncertain species or varieties of *Nicotiana* in their herbarium to send him specimens for examination, which he will promptly return. He recognizes, in a tentative classification, six varieties of *Nicotiana Tabacum* and seven of *N. rustica*.

PROFESSOR C. R. BARNES and Mr. F. D. Heald have recently sent to press a second and very greatly enlarged edition of Barnes' *Keys to the Mosses of North America*, which is to be published about Oct. 1st, as a *Bulletin* in the Science Series of the University of Wisconsin. It will make a work of from 175–200 pages, including not only a key to the published species, so far as possible, but also collected descriptions of species not described by Lesquereux and James in the Manual.

ONE OF THE FEATURES of the Innsbruck botanical garden is the planting together of plants illustrating certain ecological relations. Professor Dr. Heinricher has arranged thirteen groups among which may be noted compass-plants, climbers, humus plants, parasites, plants with weapons, etc. A list of the best representatives of each group, together with some culture notes, is given in the *Botanisches Centralblatt* **66**: 273. 1896. Other gardens with such grouping are Berlin, Munich, and Zürich.

MR. GEORGE W. VANDERBILT has imported from Europe what is considered to be the most valuable library on forestry in the world, for his Biltmore estate. Mr. Vanderbilt has started forest culture on a large scale at Biltmore, under the management of Mr. Gifford Pinchot, and has built a number of cottages on his estate for the special use of students of forestry.

As these will have access to the library mentioned, it will be, for all practical purposes, a free library.—*Book Reviews*, August.

AT THE LAST meeting of the Linnean Society, just before the summer vacation, a paper was presented by Professor D. T. MacDougal on the relation of the growth of foliage leaves to the chlorophyll function, and also one by Mr. Alfred Russell Wallace on the value of specific characters. The occasion was especially notable as being the fortieth annual meeting since the joint presentation before the society of the subject of the origin of species by Charles Darwin and Alfred Russell Wallace. The gathering in consequence took on something of the character of an ovation to Mr. Wallace.

THE DEATH of William Hamilton Gibson in the latter part of July removes an acute observer and an artist of great excellence as an illustrator. His first work was done for the *American Agriculturist*, while his later work in *Harper's Magazine* and in popular books is familiar to all. His recent studies were chiefly upon the relations of flowers and insects, upon which he had prepared a series of lectures, illustrated by most ingenious mechanical charts, showing the insects and flower parts in action. He had already done much to popularize (in its best sense) the study of plants in the field, a greatly needed work cut short by his untimely death in middle life.

THE BOTANIC GARDEN at Oxford is said to be the oldest in Great Britain. It was presented to the University in 1632 by Henry L. Danvers, earl of Danby, who spent a large sum in filling in the ground to raise it above overflow from the river that runs along one side. He also built the high stone wall about it, as it now stands. at an expense of 5000 pounds sterling. Part of the elaborate gateway designed by Inigo Jones, including the statues of Charles I and Charles II, was added later. It is a curious feature that the ground on which Lord Danvers spent such a large amount of money was not bought, although it must have been a cheap piece of land, but was leased from Magdalen College at an annual rental of thirty pounds sterling. The lease is still in force without alteration, the last renewal in December 1880, being for sixty years. There is no danger, as reported in American journals, that the lease will ever be closed or changed, unless it is the desire of the University.